# BULLETIN

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# ILLINOIS STATE LABORATORY

OF

# NATURAL HISTORY

URBANA, ILLINOIS, U. S. A.

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# ERRATA AND ADDENDA.

Page 58, line 7, for *ovalis* read *ovata*.

Page 85, line 8, for *longicaudus* read *longicauda*, and just above *Phacus pleuronectes* read the following paragraph:—

*Phacus longicauda* var. *torta*, n. var.—This variety, for which I propose the name *torta* because of the twisted body, is figured by Stein ('78, Taf. 20, Fig. 3). It occurred sparingly in midsummer from July to September, rarely in October, in 1896 and 1897.

Page 91, line 18, after *T. caudata* Ehrb. read *T. lagenella* Stein.

Pages 153, line 3 from bottom, 168, line 16, and 178, line 14, for '*98* read '*98a*.

Pages 156, line 11, 159, line 16, and 161, line 5 from bottom, for '*93* read '*98a*.

Pages 175, line 5, 186, line 3, and 208, line 17, for *Bimœrium* read *Dimœrium*.

Page 288, line, 3 for *Lampsilus* read *Lampsilis*.

Page 292, line 13, for *gracilis* read *gracile*.

Page 471, line 3 under heading beetles, for *pennsylvanicus* read *pennsylvanica*

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VOL. VIII. MAY, 1908 ARTICLE I.

THE PLANKTON OF THE ILLINOIS RIVER, 1894–1899, WITH INTRODUCTORY NOTES UPON THE HYDROGRAPHY OF THE ILLINOIS RIVER AND ITS BASIN. PART II. CONSTITUENT ORGANISMS AND THEIR SEASONAL DISTRIBUTION.

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Article I.—*Plankton Studies. V.*[1] *The Plankton of the Illinois River*, 1894–1899. *Part II. Constituent Organisms and their Seasonal Distribution.* By C. A. Kofoid.

## Introduction.

This paper gives the results of a statistical study of a series of quantitative plankton collections made in the channel of the Illinois River near Havana, Ill., at the Illinois Biological Station, in 1894–1899. The environmental conditions and the volumetric results of this investigation have been given in Part I. (Kofoid, '03), published in Volume VI. of this Bulletin.

Of the 235 collections made in channel waters and used in the quantitative study, only 182 were subjected to numerical and qualitative analysis. The omitted collections were intercalated at brief intervals of one to several days between those enumerated, principally in the summer of 1895 and during the winter flood of 1896 and the summer of the same year. The collections chosen for this study, whenever possible, represent a weekly interval, and a full list of all collections, with environmental data, may be found in Table III. of Part I. The chronological distribution of the collections studied by the statistical method is given in the table on the following page.

The work of enumeration and the primary tabulation was completed at Urbana December 31, 1900, when my formal connection with the State Laboratory ceased. The manuscript has been

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[1] The four preceding numbers of this series, all by the present writer, have been published as articles of the Bulletin of the Illinois State Laboratory of Natural History, as follows:—

Article I., Vol. V.—Plankton Studies. I. Methods and Apparatus in Use in Plankton Investigations at the Biological Experiment Station of the University of Illinois.

Article V., Vol. V.—Plankton Studies. II. On *Pleodorina illinoisensis*, a New Species from the Plankton of the Illinois River.

Article IX., Vol. V.—Plankton Studies. III. On *Platydorina*, a New Genus of the Family *Volvocidæ*, from the Plankton of the Illinois River.

Article II., Vol. VI.—Plankton Studies. IV. The Plankton of the Illinois River, 1894–1899, with Introductory Notes upon the Hydrography of the Illinois River and its Basin. Part I. Quantitative Investigations and General Results.

prepared at Berkeley, being completed in May, 1904, after my connection with the University of California was begun. My separation from the collections and the library of the State Laboratory has rendered impossible some verifications, comparisons of specimens with more recent literature, especially among the algæ,

Distribution of Collections by Months.

| | '94. | '95. | '96. | '97. | '98. | '99. |
|---|---|---|---|---|---|---|
| I | ........ | ........ | 4 | ........ | 3 | 5 |
| II | ........ | 1 | 4 | 2 | 4 | 4 |
| III | ........ | ........ | 5 | 1 | 5 | 4 |
| IV | ........ | 2 | 4 | 1 | 4 | |
| V | ........ | ........ | 4 | 1 | 5 | |
| VI | 2 | 1 | 5 | 1 | 4 | |
| VII | 2 | 4 | 5 | 3 | 4 | |
| VIII | 1 | 5 | 6 | 4 | 5 | |
| IX | 2 | 4 | 2 | 4 | 4 | |
| X | 1 | 5 | 1 | 4 | 4 | |
| XI | 1 | 4 | 1 | 5 | 5 | |
| XII | 1 | 5 | 2 | 4 | 5 | |
| Total | 10 | 31 | 43 | 30 | 52 | 13 |

some desirable amplifications from omitted intermediate collections, and the elimination of a few minor errors in the statistics.

It should be understood that the data of this paper are derived from channel collections, and the conclusions apply only to that region. Conditions of plankton development in the adjacent backwaters, as shown in Part I., differ greatly in volumetric character and seasonal distribution. The composition of the plankton and the seasonal distribution of its constituent organisms also exhibit there many points of difference from those here described for channel waters.

## METHODS.

The collections were preserved in bottles of uniform capacity (60 cm.$^3$), in alcohol-formalin mixture (2 per cent. formalin in 70 per cent. alcohol), and after measurement by the centrifuge were released from the compressed condition in the measuring tubes and returned to the containers.

The counting was done by a modified Sedgwick-Rafter method (see Kofoid, '97), in which 1 cm.$^3$ of a suitably diluted plankton is distributed evenly in a cell $20 \times 50$ mm. The plankton was diluted or condensed (from 60 cm.$^3$ of fluid) according to the quantity of plankton and the amount and nature of the silt. Larger organisms such as the *Entomostraca* were counted in the whole catch, or in larger collections in $^1/_{10}$ to $^1/_{50}$ of the total catch; and the smaller organisms in $^1/_{25}$ to $^1/_{400}$. The filter-paper catches which supplemented those of the plankton net from August 3, 1896, to the end of the series, March 28, 1899, were often subjected to considerable dilution on account of the great amount of fine silt in the collections, from $^1/_{10}$ to $^1/_{100}$ being the limits of dilution as a rule.

The even distribution of the organisms in the Rafter cell was secured by shaking the collection in a mixing cylinder gently till the sediment was thoroughly distributed, and taking the sample immediately with a long 1 cm.$^3$ pipette, inserted to the bottom of the jar and raised to the surface during the filling process, and by discharging the contents immediately into the cell at one corner, the cover having been previously displaced at a slight obliquity to admit the end of the pipette. With the filling of the cell the cover automatically moves into place, and practice soon enables one to fill the cell without inclusion of air bubbles. With the exception of the heavier rhizopods, all of the organisms are as a rule very evenly distributed by this method.

The identification and enumeration of the contents of the cell were carried on with the help of a mechanical stage and a $\frac{2}{3}$ Bausch & Lomb objective, with a Zeiss C for higher magnification when needed for the detection of fine details or for counting the smaller organisms in the filter-paper catches.

After considerable experimenting, the following method was established in the work of enumeration. Four sheets, each with numbers 1 to 76 at the left, were fastened temporarily to accompanying key sheets, each number on each sheet standing for one of the more common species. One sheet was assigned to algæ, diatoms, and miscellaneous organisms; and one each to *Protozoa*, *Rotifera*, and *Entomostraca*. As the plankton sample was examined under the microscope the identifications were called off, and entered on the sheets by a clerical assistant. Six of the most abundant species were recorded by the observer himself on six tallying machines registering 1,000, and conveniently arranged in a box at his right. By adjusting the springs to give different sounds when registry was made, and by modifying the surfaces pressed by the fingers so as to differentiate the several machines without looking at them, it was possible to use these without raising the eye from the microscope, and thus to avoid the fatigue arising from the repeated muscular readjustment of the eyes necessary when the observer makes his own entries in a written record. Common species not recorded by the tallying machines were generally abbreviated or designated by easily-called tokens. When once fairly familiar with the species it was possible by means of these labor-saving devices to make identifications and enumerations of several heavy planktons per day.

By a number of tests I found that when the enumerations of a species in a given collection reached 1,000, little was gained by carrying it to higher numbers. A limit of error of $\pm 5$ per cent. can be thus obtained if the species in question is distributed evenly in the cell and all precautions are observed to secure accuracy. Enumerations were often carried beyond this point, but rarely beyond 3,000. The accessions numbers of the collections from our catalog of collections served to designate each sheet of data and all note slips bearing on the collection or its constituent organisms. When the enumeration was completed, the factors of collection, dilution, and enumeration were entered on the sheets, and the number of individuals of all species represented was computed and carried to the right of the sheet. The totals of the various groups—for example, diatoms or *Cladocera*—were then added up and entered on the sheets in differential colors. By the use of the key sheets the number per $m.^3$ of water of any given species could be quickly ascertained. Species not in the key were entered by name on the sheets.

When the enumeration of all collections was completed, the numbers per $m.^3$ giving the seasonal distribution of the various species and groups through the collections of 1894–1899 were drawn up on uniform folio sheets, and the annual totals and averages computed therefrom. With the data in these forms it is possible to turn at once to the statistics of the plankton of a given day, or to the seasonal distribution of any desired species.

## ACKNOWLEDGMENTS.

I am indebted to Prof. S. A. Forbes, Messrs. E. B. Forbes, F. W. Schacht, and R. W. Sharpe for many suggestions concerning the *Entomostraca*; to Prof. Frank Smith for assistance with the *Oligochæta* of the plankton; and to Mr. A. Hempel for my introduction to the *Rotifera*. The identification of the cosmopolitan species of the fresh-water plankton of the Illinois River was greatly facilitated by the most excellent library of the Illinois State Laboratory of Natural History, the accumulation of many years' careful selection by its director, Prof. S. A. Forbes. The literature of fresh-water fauna, and to a large extent of its flora also, is very fully represented therein. The excellent Laboratory collection of identified Entomostraca from European specialists was also of great service.

I am indebted to Mr. R. E. Richardson for valuable services as clerical assistant, and for substantial help in organizing the great mass of data resulting from the enumerations.

Except as noted in the discussion in subsequent pages, I hold myself responsible for all of the identifications of the species recorded. The enumeration is also all my own work, with the exception of that of the nauplii, of two species of *Difflugia*, and of *Pediastrum* in about one third of the collections, in which I had the assistance of Mr. R. J. DeMotte, and that of the commoner *Rotifera* in a few of the collections, which were counted by Mr. Richardson.

## DEFINITIONS.

The term "plankton" was used by Hensen ('87) to designate "Alles was im Wasser treibt." It was applied by him only to that assemblage of *marine* organisms which float passively in the open sea, without active recourse to shore or bottom, and unable by their own efforts materially to change their location. The term has since been extended also to assemblages of organisms in fresh water which bear a similar relation to open water. This fresh-water plankton has been designated in turn "limnoplankton" by Haeckel ('90), a word which in a restricted sense is retained for the plankton of lakes, while that of rivers has been distinguished by Zacharias ('98a) as "potamoplankton," and that of ponds ('98) as "heleoplankton." These distinctions are based upon the nature of the environing body of water, and the terms are convenient, though the separation of these types everywhere in nature is difficult, if not impossible. Owing to the smaller size of fresh-water basins as compared with those of marine character, the shore and bottom become more important as factors in the environment of the plankton. Within the fresh-water environment we also find degrees of importance of the shore and bottom which in ascending scale dominate in the lake, river, pond, and marsh. Although each of these represents distinct conceptions, in nature we find them imperceptibly intergrading, and neither these conceptions, geographical nomenclature, nor local parlance give us any final criterion which will enable us to use the terms with the precision which a scientific terminology would demand. The distinctions between these forms of fresh-water plankton must lie in the plankton itself, if anywhere. As I shall attempt to show later, these distinctions, though apparent, in some cases at least, are nevertheless of minor importance, and depend very largely upon the relative predominance of the adventitious littoral fauna and flora rather than upon distinctive assemblages of eulimnetic species. The striking similarity of this eulimnetic plankton in all these types of environment and in widely separated continents is a biological phenomenon of far more significance than these minor differences. These distinctions between the different types of fresh-water plankton are thus more a matter of terminology than of biological import.

Among the organisms found in open water there are varying degrees of dependence upon the shore and bottom. Some, as *Cyclops* and many of the lower algæ, have life cycles in which no encysted or quiescent resting stage has been found, and actively or passively their whole existence is passed in the open water. They are at all times components of the plankton; that is, are *continuous planktonts*. Others, as *Dinobryon*, many of the *Rotifera* and *Cladocera*, and, in fact, the greater part of the eulimnetic organisms, have an encysted stage which as a winter egg or a cyst descends to the bottom and remains there for a season. Such organisms only periodically, wholly or in part, leave the open water for a littoral or benthal existence. They are *periodic planktonts*. Some organisms, such as many of the rhizopods and diatoms and *Hydra*, appear in the plankton under certain conditions of temperature and food. They temporarily adopt the limnetic mode of life as a result either of a change in their specific gravity due to internal changes, such as an increase of the gaseous or fatty contents of their protoplasm, or to changes in the buoyancy of the water due to changes in temperature or in substances in solution in the water, or because of the abundance of food in the open water. They become under these conditions *actively adventitious planktonts*. Still other organisms are released from their usual contact with or attachment to the substratum, or from their association with debris or vegetation of shore or bottom, by movements or disturbances in the water, and are swept into the open water only to return again to their customary habitat when conditions favor. Practically all of the smaller organisms inhabiting the shore and bottom and the debris and vegetation found thereon are liable thus to enter the open water, and to be found in forced and temporary association with the eulimnetic fauna and flora. They are *passively adventitious planktonts*.

Another class of organisms which occur in the plankton are those which either as internal or external parasites find in plankton organisms either a host or a substratum for attachment. These are in a certain sense passive planktonts, and they may be distinguished from other passive planktonts as *attached* or *parasitic planktonts*. Sharp lines between these various classes of organisms found in open water can not be drawn upon distinctions based upon their degree of dependence upon the bottom and shore. An equally vague line separates the organisms of the plankton from those more active forms which by virtue of their powers of locomotion are to a considerable degree independent of waves and current, and are able freely to maintain their position in their preferred habitat. Among the organisms commonly included in the plankton, the flagellates, rotifers, and *Entomostraca* exhibit some degree of activity, such as is seen in their limited vertical migrations, while larger organisms, such as *Leptodora hyalina* and the larvæ of *Corethra*, are capable of movement sufficient to give them considerable independence in the matter of their position in the water. We thus find degrees of independence which approach closely that found in young fish and the large insect larvæ—organisms not always regarded as planktonts.

The plankton is thus a composite assemblage of organisms whose association depends in varying degrees upon their relation to their common habitat, the open water. In actual practice, all the organisms found in the open water are regarded as within the scope of plankton investigations, and justly so, for by virtue of their presence they become more or less involved in the complex interrelations which pertain to the flux of matter, the succession of species, and the food relations which exist through the changing seasons in the aquatic environment.

In our own investigations it has been our purpose to include all the organisms found in our collections; that is, all which our methods of examination give us a sufficient means of investigating. Naturally, the bacteria are to large extent excluded from our consideration, though they properly belong to the plankton, and in the processes of nitrification and denitrification play an exceedingly important part in the economy of aquatic life.

## THE COMPOSITION OF THE PLANKTON.

The composite character of the plankton is especially marked in streams,—as, for example, in the Illinois River,—owing to the mingling of organisms from a great variety of tributary sources—backwaters, lakes, ponds, pools, marshes, swamps, brooks, rivers, canals, sewers, drains, and industrial wastes. Few lakes possess so varied a supply, and in none can the proportional effect of these contributions exceed that of the stream. Added to this contributed assemblage, and in some seasons predominating over it, is the indigenous or autonomous plankton of the stream itself.

The component organisms of the plankton of the Illinois River number 528 forms, including only those which have been identified from collections made in the main stream and including both species and well-defined forms or varieties. Species found thus far only in the backwaters are not included, though there is little doubt that they occur also in the main stream. No effort has been made to build up merely a long list of species, but only to identify, so far as possible, the common and recurring forms. Neither has any attempt been made to establish new species or revise those already described, though a magnificent opportunity awaits the naturalist who has the fortitude to analyze the exceedingly variable forms which compose the plankton, and to determine by modern methods which of these variants are entitled to specific rank. It has seemed to the writer that the only satisfactory basis upon which species, and pre-eminently those of the fresh-water plankton, can rest, lies in a careful determination of the limits of seasonal and local variation within the area of distribution. This means breeding under control, and the study of variation by modern statistical methods. Both of these lines of inquiry lie beyond the purpose of the present paper, and plainly beyond the possibilities of accomplishment by any one investigator, when the great number of species and the present state of the literature of the subject is considered. It is becoming constantly more evident that the species of the plankton are in the main cosmopolites, and the world literature of the subject must be taken into consideration in any thorough attempt to handle the systematic side of the subject. During the progress of this work, which was begun in 1894, every effort was made to secure all pertinent literature bearing on the genera of plants and animals represented in the plankton, and so far as possible in the enumeration of the collections the individuals were referred to "species" already described, or, in default of this, recorded as "unidentified." In some groups—notably the desmids, diatoms, and unicellular algæ—it was not possible under the conditions of plankton enumeration to apply to all the individuals enumerated the fine distinctions which specialists in these groups have made. They have been thrown under certain of the better-defined species, which thus stand in our records as representatives of closely related variants as well as of the types of the species named. Examples of this appear in *Closterium*, where two species only were listed. Probably a number of so-called species among the scores described in this genus will be found among the individuals in our plankton here referred to the two species *C. acerosum* and *C. lunula*. So, also, in the case of *Melosira*; two principal types were listed, *M. varians* and *M. granulata*,—though even these two seem at times to intergrade. Other described species will be found among the individuals thus distributed. In the case of *Difflugia globulosa* and *D. lobostoma* a large number of intergrading and variable forms are included. It would be possible to find among these, representatives of many recently described species. In these instances the difficulty lies not so much in finding representatives of these closely related species, but, rather, in drawing the lines between them and placing every individual enumerated in the proper pigeon-hole. To avoid this difficulty, the separation was not attempted in every case. With the hope that the results would throw some light on the question of seasonal variation, this separation was attempted in the genus *Brachionus*, where the species characters are confined to prominent structural features.

So far as it was feasible, specific distinctions were accepted as found, and utilized whenever possible. In the lists and discussions which follow, the inclusion of a species does not necessarily carry with it the inference that it is regarded by the writer as valid or well founded. It merely represents in our enumerations a more or less continuous succession of organisms which conform approximately to the descriptions and figures of the species designated by the name in question. Inferences regarding the rank or validity of the species reported will be given whenever the statistical data or my observations on the variability of the organism seem to afford data bearing on the standing of the species. While not a few of the species reported may justly be regarded as synonyms, an effort has been made to use only names which represent valid species or at least a variety or a seasonal form.

## COMPARISON OF FRESH-WATER AND MARINE PLANKTON.

The plankton of fresh water is very generally composed of an assemblage of organisms, of plants and animals, principally cryptogams and invertebrates. Not all orders are represented, and those that do occur vary greatly in the number of their representatives. The fresh-water plankton differs from that of the sea in the almost universal absence of larval forms, in the smaller number of invertebrate groups represented, and in the smaller size of its component organisms. Fresh-water plankton has almost no limnetic cœlenterates, *Hydra fusca* being the only representative as yet discovered in our locality. The absence of the larger *Crustacea*, of limnetic mollusks and worms, and of tunicates and *Radiolaria* robs limnetic life of the diversity found among pelagic organisms of the sea. The only larval stages found in our locality are the glochidia of the

*Unionidæ*, whose limnetic sojourn is at the best but brief, and the larvæ of certain dipterous insects, such as *Chironomus* and *Corethra*. The limnetic habit of these larvæ is hardly established as yet. The small size of fresh-water planktonts as contrasted with those of the sea is very striking. Representatives of the same group—for example, the *Dinoflagellata* and the *Entomostraca*—in the two habitats exhibit this contrast. The largest entomostracan of fresh water is less than a centimeter in length, and there is nothing to compare with the pelagic cœlenterates, *Mollusca*, or such tunicates as *Salpa* and *Pyrosoma*. The smaller size of fresh-water planktonts may be due to the lower specific gravity of the environing medium, and perhaps also to the effect of smaller quantities of dissolved salts upon the metabolic processes of limnetic animals.

Notwithstanding this absence of large individuals in the plankton of fresh water, the total quantitative production of plankton per cubic meter is greater here than in the sea. For example, the average production in the Illinois River is 2.71 $cm.^3$, and the average amount in adjacent backwaters rises as high as 22.55 $cm.^3$ (in Phelps Lake). These measurements were made by the centrifuge, and the results of the "Plankton Expedition" of Hensen reduced to this basis of measurement by Krämer ('97) show that the Atlantic Ocean at the time of this expedition had in the upper strata examined but 0.12 to 0.48 $cm.^3$ of plankton per cubic meter.

## ORGANISMS OF THE PLANKTON.

The groups of plants represented in the plankton of the Illinois River are principally algæ, of which the *Bacteriaceæ* are but partially retained in the collections and are usually omitted in plankton investigations. The *Schizophyceæ*, or blue-green algæ, furnish a few important representatives and a number of adventitious species. The *Chlorophyceæ*, or green algæ, on the other hand, abound both in species and individuals, and afford an element of great importance in the primal food supply. The *Bacillariaceæ* are exceedingly abundant, and are represented by a number of eulimnetic, as well as many adventitious, species. They also constitute one of the primal sources of food for the zoöplankton. The *Conjugatæ* furnish but few species and individuals—principally desmids—to the phytoplankton. The phanerogams afford a few species which are often taken with the plankton by virtue of their semi-limnetic habit, but do not in the living state enter the food cycle of the plankton nor affect its economy except as competitors.

The zoöplankton includes representatives of a considerable range of groups, though both in species and individuals the *Protozoa*, *Rotifera*, and *Entomostraca* predominate among the animals. Representatives of other groups are in the main adventitious.

Among the *Protozoa*, the *Rhizopoda* are constantly represented by many individuals and a considerable number of species, many of which may be adventitious, but most of which are wont to adopt the limnetic habit during the warmer months. The *Heliozoa* are few both in species and individuals. The *Mastigophora* (which in our discussions include all green and brown flagellates often classified with the *Chlorophyceæ* and *Phæophyceæ*) vie with the *Chlorophyceæ* and *Bacillariaceæ* for the first place as converters of the inorganic (and perhaps also the dissolved organic) matter into food for the zoöplankton. They are exceedingly numerous in our plankton both in species and individuals, and form quantitatively a considerable part of the plankton during the summer months. The usual method of plankton collection—by silk bolting-cloth—permits a large proportion of these organisms to escape. The *Ciliata* furnish a few constant members of the plankton, and numerous adventitious and parasitic species. During the low water of autumn, when bacterial contamination is at its height, these organisms form a large part of the plankton. The small size of some of the ciliates, combined with their motility and flexibility, renders the loss by their escape through the silk net considerable. The *Suctoria* furnish but few species and individuals—mainly adventitious or attached to other planktonts.

The *Rotifera* constitute, both in species and individuals, the most important single group of analytic organisms, that is those of distinctly animal metabolism, occurring in our plankton. This may in part be due to our shallow warm waters and to the abundance of *Chlorophyceæ* and *Mastigophora*, which enter largely into their food. This abundance of the *Rotifera* may prove to be characteristic of the plankton of rivers ( potamoplankton) as contrasted with that of lakes (limnoplankton). While many rotifers are eulimnetic, the plankton also contains numerous adventitious species.

The *Entomostraca* include the largest fresh-water planktonts, and in every respect constitute an important element of our river plankton. They form the final link in the food cycle which connects the nutrients in solution in the water and in decaying detritus with the fish and other aquatic vertebrates. They include numerous species, some of which are adventitious. All of the *Ostracoda* belong to this latter class. The *Cladocera* furnish some of the most important eulimnetic species and a large number of adventitious forms, while the *Copepoda* are almost wholly eulimnetic.

In addition to these groups, the *Turbellaria*, *Oligochæta*, *Hexapoda*, *Hydrachnida*, *Gastrotricha*, and *Bryozöa* furnish a few species and individuals of a semi-limnetic or adventitious character to the plankton.

In the table which follows, these various groups are listed, and the number of forms occurring in each is noted. In order to give some idea of the proportionate representation of these groups in our plankton, the table includes the sum of the number of individuals per $m.^3$ of water in the weekly collections for the year 1898. This was a year of no marked departure from the normal regimen of hydrographic conditions (Part I., Pl. XII.). The summer and autumn flushes tend to lower the population somewhat below that of more stable seasons, but beyond this feature there is nothing to suggest that the plankton of this year may not represent a fair average of that recurring each year in the Illinois River. The figures given, in all cases refer to the number of individuals per cubic meter (excepting only such cases as *Synura* and *Uroglena*, where the colony rather than the individual becomes the unit). The algæ and *Protozoa* include many species enumerated in filter-paper collections, which accounts for the large numbers in some of the totals. The "number of forms" listed refers to the total number found in the waters of the river during the period of our operations. Some species not noted in 1898 are therefore included. Unidentified forms are not included in the list of number of species, though the groups here listed to which they belong were known. Some forms referred to genera but not determined as to species are, however, included.

This table throws some light upon the ecological relations of the groups composing the plankton, since it gives some clue to their relative numbers, and these condition in a general way the food relations existing between the different groups. The plants are more abundant (and generally smaller) than the animals, outnumbering them nearly 5 to 1. Computation shows that for each one of the *Cladocera* there are 7 *Copepoda*, the predominance of the latter

Constituent Groups of the Annual Plankton of the Illinois River. Average of 52 Weekly Collections in 1898—number per m³.

| | Number of forms recorded. | Number of individuals. |
|---|---|---|
| Algæ: | | |
| Bacteriaceæ | 3 | (57,142,822)* |
| Schizophyceæ | 9 | 85,909,985 |
| Chlorophyceæ | 33 | 53,175,105 |
| Bacillariaceæ | 29 | 396,192,716 |
| Conjugatæ | 7 | 48,459 |
| Phanerogamia | 2 | 9 |
| Total phytoplanktonts | 83 | 535,326,274 |
| Protozoa—total | (185) | (111,731,000) |
| Mastigophora | 68 | 95,856,449 |
| Rhizopoda | 59 | 55,364 |
| Heliozoa | 5 | 4,871 |
| Sporozoa | 3 | 1,638 |
| Ciliata | 45 | 15,812,346 |
| Suctoria | 5 | 332 |
| Rotifera | 104 | 592,416 |
| Entomostraca—total | (43) | (47,041) |
| Cladocera | 26 | 6,242 |
| Ostracoda | 4 | 191 |
| Copepoda | 13 | 40,608 |
| Miscellaneous | 114 | 9,393 |
| Total zoöplanktonts | 446 | 112,379,850 |
| Total planktonts enumerated | 529 | 647,706,124 |
| Synthetic (chlorophyll-bearing) | .......... | 613,017,986 |
| Analytic (non-chlorophyll-bearing) | .......... | 34,687,781 |

being accounted for in part by the fact that their larval stages are free-swimming and appear in the enumerations, while the young of the *Cladocera* are not set free until nearer maturity. About 10 to 20 per cent. of the *Copepoda* are adults. The relative numbers of

* Represents fragments of filaments, and is not included in totals.

the two groups are not so disproportionate as the figures might seem to indicate. For each one of the *Cladocera* there are 95 rotifers and almost 18,000 *Protozoa.* The latter are distributed as follows: There are 9 rhizopods, almost 2,400 ciliates, and over 15,000 flagellates for each one of the *Cladocera.* There are also about 86,000 plants for each of these *Cladocera.* Of these plants, 64,000 are diatoms, 14,000 are *Schizophyceæ,* 9,000 *Chlorophyceæ,* while but 8 are desmids. The great abundance of diatoms, of green and blue-green algæ, and of chloryphyll-bearing flagellates affords, it would seem, an abundant food supply for the zoöplankton. If of the *Mastigophora* the colorless flagellates only be retained in the zoöplankton, and the remainder—which are predominantly synthetic forms—be included with the phytoplankton, we find the latter outnumbering the analytic organisms (zoöplankton) 18 to 1. Quantitative values in the matter of food relationships are not readily determined except by a combination of the chemical and experimental method. These results by the statistical method express, with more or less error, the equilibrium of the biological components in terms of the individual organisms.

## Discussion of the Statistical Data of the Species composing the Plankton of the Illinois River in 1894–1899.

In the following pages the organisms occurring in the plankton of the Illinois River will be recorded, and from the statistical data accumulated by the enumeration method, facts pertaining to their relative abundance, seasonal distribution, and periods of maximum occurrence will be cited. The average number per cubic meter for the year 1898 will be given, based upon the averages of 52 collections distributed regularly throughout the year (Part I., Table III.). This year is chosen because of the regularity of the times of collection and the absence of any considerable irregularity in the hydrograph. Statements concerning seasonal distribution, etc., are based upon the records for all the years—1894–1899. All figures pertaining to species or groups marked with an asterisk, and starred figures elsewhere, are based upon filter-paper catches; all others, upon those of the silk net. Temperatures are in Fahrenheit, and are of surface waters at time of collection.

The margin of error in statistical work of this sort is confessedly large. The complex character of the data with which I am dealing, and especially the extreme range in numbers, have made it necessary that I should adopt some consistent method of treating the computations. I have therefore chosen to carry out the numbers to units, as the most feasible method of avoiding confusion in the handling of the data. The use of round numbers would have been just as accurate. Computation to units is therefore to be understood as a matter of convenience, and not as an effort to exhibit a false and unattainable accuracy.

### CRYPTOGAMIA.

#### BACTERIACEÆ.*

Records were kept of the masses of the larger members of this group which occurred in our plankton catches. They were principally the dichotomously branched brownish fragments of *Crenothrix*, filaments of *Beggiatoa*, and colonies of *Micrococcus*. The average number recorded for this year was 57,142,822, and they occur throughout the year in every collection, rarely falling below

10,000,000 per m.$^3$, and reach their maximum development (over 600,000,000) in winter months (December to February), especially during low water and more stable conditions, as in January, February, and December, 1898 (Pt. I., Pl. XII.). At such times the temperature is at or near 32°. With flood conditions and rise in temperature the numbers fall below 100,000,000, running from 10,000,000 to 50,000,000 during most of the summer. The decline is due in part to the dilution by flood waters, and largely to the retreat up the stream of the crest of the wave of bacterial activity caused by the Peoria pulse of sewage. As noted in the discussion of the chemical conditions, in Part I., this wave lies considerably above Havana during the warmer months. Summer floods, as in June and September, 1897, are wont to wash into the river large quantities of these organisms, bringing the numbers up to 300,000,000 at times. The figures above cited give but a feeble representation of the real conditions in the river during this period of maximum. Many of these organisms become attached to objects along shore, and accumulate in great quantity in quieter waters along the channel. They form a serious menace to the fishing industry, since they accumulate in a day or two upon the fyke-nets in quantity so great that their weight and resistance to the current are sufficient to break down the nets. Their effect upon the constitution of the plankton is seen in the marked increase in certain ciliates which accompanies the maximum of these organisms.

### SCHIZOPHYCEÆ.

Nine forms were recorded, though a number of others which occurred but rarely in the plankton remained unidentified. The average number (combined silk and filter-paper records, but omitting the former when the latter are available) is 85,909,985 per m.$^3$ This group contributes to the plankton throughout the year, and though numerically abundant is quantitatively less important, owing to the small size of its most abundant member, *Microcystis.* This species and *Oscillatoria* constitute quantitatively the greater part of the blue-green algæ of the plankton. In contrast with the plankton of Lake Michigan, there is a noticeable decrease in the proportion of *Anabæna* and *Clathrocystis. Rivularia*, *Gloiotrichia*, and *Aphanizomenon flos-aquæ*, often reported in fresh-water plankton, were not found in our fluviatile environment. This group contributes to the water-bloom, contains a number of adventitious planktonts, and is one of the primal sources of the food supply. In our waters it seems to be quantitatively much less important than either the *Chlorophyceæ*, the *Bacillariaceæ*, or the synthetic *Mastigophora*.

DISCUSSION OF SPECIES OF SCHIZOPHYCEÆ.

*Anabæna spiroides* Klebahn.*—Average number, 637,692 (silk 15,431). In the water-bloom from the last of June till the end of October. Not noted in 1898, but not infrequent in 1897—a low-water year. Temperature range, 60°–89°. Data insufficient to determine maximum. Largest number recorded, 7,200,000, June 28.

*Clathrocystis æruginosa* (Kütz.) Henfr.—Average number of colonies or masses, 83. More abundant in the previous low-water year. From May till the end of November in the water-bloom. Predominantly a midsummer species. Maximum in August and September (108,000). Confined principally to the low water of midsummer, appearing when the water reaches a temperature of 70°, and reaching its maximum development in temperatures above this point, declining at once to small numbers (less than 1,000) when the temperature falls below 60°, but lingering till the water approaches the freezing point late in November.

*Merismopedia glauca* (Ehrbg.) Näg.—Average number of colonies, 93. In 1897, 889,412.* In the water-bloom. Recorded from July till the end of October, and also singly in January and February. It was more abundant in 1897 than in 1898, and the maximum number (15,840,000*) appeared on August 31.

*Microcystis ichthyoblabe* Kütz.*—Average number, 83,059,615. Recorded in all collections throughout the year, except in some flood waters of February and March, when the silt probably obscures it. Minimum numbers (less than 50,000,000) prevail during cold months, November to April, when the temperature ranges from 32° to 50°. A well-sustained pulse exceeding 200,000,000 appears with the volumetric plankton maximum of April–May (Pt. I., Pl. XII.) and declines to the previous minimum with the falling off in the plankton. The maximum pulse appears later, in August and September in 1898, in September and October in 1897, averaging about 200,000,000, and reaching 1,697,000,000 August 9, 1898. The temperatures during these pulses are above 60°, and the period of the maximum comes toward the close of that of maximum summer temperatures, and sometimes in the autumn decline (Pt. I., Pl. XI. and XII.), when low and often stable river-levels usually prevail. A vernal and an early autumnal pulse are thus both present in the distribution of this species. It is not improbable that other species than the one named have been included in the enumeration along with it on account of the small size and lack of striking characteristics. There are suggestions of recurrent pulses at intervals of 2–6 weeks in the records (Table I.).

*Oscillatoria* spp.—Average number, 15,431 (filter-paper, 637,692). The probable inclusion of several species in the sums under this heading may account in part for the irregularity of the seasonal curve. *Oscillatoria* has appeared in every month of the year, though the occurrences were most frequent in the period from July till the first of October. The numbers are exceedingly irregular and variable, and the pulses of numbers seem to attend the initial stage of floods following stable conditions. Thus, while these organisms occurred but singly or sparingly in the plankton during the autumn of 1897, they rose to 277,200 with the flood of January 11, 1898, doubtless torn loose by the current from the bottom—their normal habitat. They are thus usually adventitious additions to the plankton. Their frequent irruption into the plankton during midsummer and early autumn, and to some extent at other times, is due in part to the evolution of marsh gas in the detritus on the bottom. This breaks up the mats of *Oscillatoria* which coat the bottom and distributes them through the upper levels, where they remain in suspension for some time. This phenomenon is more prevalent in the marshy backwaters than it is in the river. Flood invasion in midsummer into the backwaters, such as Quiver Lake, is wont to cause there stagnation and great increase in *Oscillatoria*, which to some extent enters the river with the run-off of the flood. Movements in the water and the evolution of marsh gas are thus principally responsible for the presence of *Oscillatoria* in the plankton. It still remains possible that its flotation during periods of optimum conditions of growth may be due to internal physiological conditions which lower the specific gravity of the organism. Its great abundance at times in upper levels in the backwaters suggests the action of this factor, and if this be true, it becomes a temporary rather than an adventitious planktont. Temperatures seem to bear little relation to the occurrence of *Oscillatoria* in the plankton.

*Tetrapedia emarginata* Schröd.*—Average number, 242,308. From the first of August till the end of October in numbers from 1,000,000 to 3,500,000 per m.$^3$, appearing later and in larger numbers in October in 1897 than in 1898. At temperatures above 65°.

*Tetrapedia gothica* Reinsch, *Glœocapsa polydermatica* Kütz., and *Glœocapsa* sp. were recorded once or twice in the midsummer plankton in relatively small numbers.

## CHLOROPHYCEÆ.

(Plates I. and II.)

Average number, 53,175,105, including, without duplication, species from both silk and filter-paper collections. In 1897 this was very much greater (139,739,850), owing to the prolonged low water and higher temperatures of the late autumn. Although abundant, these organisms are outnumbered by the diatoms six to one, and by the synthetic *Mastigophora* by about two to one. The *Chlorophyceæ* of the plankton, with few exceptions, are minute, and generally escape through the silk net. *Pediastrum* and colonies of *Botryococcus* are about the only species of which the usual method of plankton collection in our waters affords a fair representation.

The *Chlorophyceæ* appear in every collection examined throughout all the years of our operations, with the exception of eight in midwinter floods in 1895 and 1896. As a group they are adapted to the whole range of temperatures, and exhibit in 1897, on April 28, a well-defined vernal pulse of 367,200,000, and a series of autumnal pulses culminating September 21 at 216,000,000, October 19 at 367,200,200, and November 23 at 52,000,000. In this year the midsummer pulses are of minor importance in comparison with those of spring and autumn. In 1898 the vernal pulse is also well defined, culminating May 3 at 212,406,400, and it is followed by a series of four midsummer pulses of considerable magnitude, which culminate June 14 at 46,000,000, July 19 at 277,000,000, August 9 at 370,000,000, and August 30 at 189,000,000. The autumnal pulse appears September 27, attaining 70,526,400. The summer and autumn hydrographs of this year are much more disturbed than in the previous year (cf. Pl. XI. and XII., Pt. I.), especially at the time of the autumnal pulse. This may account for the contrast in the two years. The *Chlorophyceæ* as a whole exhibit (Pl. I. and II. and Table I.) the tendency to form a seasonal curve of recurrent pulses at approximately monthly intervals (three to six weeks), which generally coincide with those of other chlorophyll-bearing organisms.

Thirty-three forms of *Chlorophyceæ* were recorded, and closer inspection of the collections will undoubtedly yield a considerable additional number either of closely related, and therefore included, species, or of those which occur but occasionally or in small numbers in the plankton.

Numerically the leading species in the order of their importance are *Scenedesmus quadricauda*, *Crucigenia rectangularis*, *Actinastrum hantzschii*, *Raphidium polymorphum*, *Scenedesmus genuinus*, *S. obliquus*, *Richteriella botryoides*, *Ophiocytium capitatum*, *Oocystis naegelii*, *Cœlastrum cambricum*, *Oocystis solitaria*, and *Schroederia setigera*. With the exception of *Botryococcus braunii* and the species of *Pediastrum*, the remaining forms are both quantitatively and numerically of minor importance. The species just named were enumerated only in the silk-net collections, and cœnobia rather than individual cells were listed. If allowance is made for the loss of small individuals through the silk, and for the increase that would follow if individuals rather than cœnobia were the basis of representation, *Pediastrum* would occupy a place in the front rank of importance in the *Chlorophyceæ* of the plankton numerically as well as quantitatively. As quantitative factors in the ecology of the plankton, *Pediastrum*, *Scenedesmus*, *Cœlastrum*, and *Botryococcus* take precedence over the smaller, though more numerous, forms, such as *Raphidium* and *Crucigenia*.

The group is thus well represented in our plankton both in species and individuals. The leading planktonts of the group reported in European and other waters in lakes and rivers are here represented almost without exception by identical or closely related species. *Botryococcus* alone seems to be less abundant than in lakes—at least, according to my own observations, it is much more abundant in the summer plankton of Lake Michigan than in that of the Illinois River. The maximum numbers of *Pediastrum* reported by Apstein ('96) for Dobersdorfer See in July, when reduced to number per $m.^3$, are frequently equaled or surpassed in our waters.

Data for comparisons in the case of the more minute organisms which escape the silk are lacking, since results of supplementary methods have not, up to the present, been published elsewhere. It seems probable, however, that the *Chlorophyceæ* will be found to be somewhat more characteristic of the plankton of rivers than of lakes, and to be more prevalent wherever the shore with its decaying vegetation forms a large factor in the environment or where sewage contamination affords the requisite food for their development.

DISCUSSION OF SPECIES OF CHLOROPHYCEÆ.

*Actinastrum hantzschii* Lagerh.*—Average number, 199,038 (silk net, 338). From May until the middle of November, with maximum of 21,600,000 on August 30, 1898, and of 122,000,000 on September 21, 1897. There are also indications of a vernal pulse, which on May 25, 1897, attained 90,000,000. The major pulse occurs late in the summer, in August and September, while diminished numbers continue until the first of November. Three single occurrences were noted in January, 1898, following the unusual prevalence of 1897, but aside from these the species occurs in the plankton at temperatures above 45°, and both pulses lie in temperatures above 65°. As in many other species, a greater development was attained in 1897, in stable low water, than in 1898 in disturbed hydrographic conditions. This species occurs in the water-bloom, is favored by stable conditions, and finds its optimum temperature between 65° and 80°.

*Botryococcus braunii* Kütz.—Average number of colonies, 75. In previous years it was much more abundant, averaging 3,300 in 1897. It occurs from the first of April well into October, though in 1897 it continued until the middle of December. It may thus appear throughout the whole range of temperatures, 32° to 90°, but as a rule occurs above 60°. There is a suggestion of a minor pulse in June, 1896, but not in other years. The major pulse attains 57,200 on August 15, 1896, and 42,000 on September 14, 1897, and appears, with smaller numbers, in August of preceding years. The species occurred but sparingly in 1898. It is found in the water-bloom, and is more abundant in the backwaters than in the main stream.

*Cœlastrum cambricum* W. Archer.*—Average number of cœnobia, 640,384 (silk, 477). Occurs from the latter part of March till towards the end of November, but principally from May through October. There are but slight indications of a vernal pulse, which on May 25, 1897, culminates at 3,600,000. The major pulse culminates at 10,800,000 on August 9, 1898. In the low water and prolonged high temperatures of 1897 the major pulse continues through September, culminating on the 21st at 32,000,000. The average number in this year was about four times as great as in 1898. The temperature limit is 43°, though occurrences are few and numbers small below 65°. The maximum development appears within the period of maximum heat, and towards its close. It is characteristic of the plankton of late summer and early autumn.

*Crucigenia rectangularis* Näg.*—Average number of colonies, 7,153,846. Recorded in all months but March and April, but sparingly from November till May. In 1897 pulses appeared in August, September, and October, attaining 32,400,000, 57,600,000, and 118,800,000, respectively. In 1898 there was but a single pulse—in August, of 158,400,000. It was more abundant in the former year. It is present continuously in large numbers from July to October, though in 1897 the impetus of the unusual development was manifested by the continuance of the species even into January. The optimum temperatures lie above 70°, in the latter part of the period of maximum heat, though the species has been found in the plankton throughout the whole range of temperatures. The abrupt decline in numbers occurs between 65° and 40°. It is characteristic of the plankton of late summer and early autumn.

*Golenkinia radiata* Chodat.—Average number of colonies, 519,231. It appears most abundantly during the April–May plankton pulse (7,200,000) and again, in increased numbers, at the end of August, thus suggesting a vernal and a late summer maximum. It seems to be most abundant at about 60°, a temperature somewhat below the optimum for the two preceding species. Two occurrences in December, 1896, and large numbers in August indicate its adaptability to the full range of temperatures.

*Oocystis naegelii* A. Br.*—Average number, 207,692. In 1897, much more abundant (average, 4,243,235). Present in numbers (over 5,000,000) from the end of May till the end of September. In 1897, pulses of 10,800,000, 46,800,000, and 24,750,000 appear in May, July, and September respectively. Both numbers and occurrences are much less in 1898. The optimum conditions thus lie above 70°, though isolated occurrences in March and December indicate its presence throughout the whole range of temperatures. It appears to be a summer planktont without the marked preference for the close of the period of maximum heat noted in some other *Chlorophyceæ*.

*Oocystis solitaria* Wittr.*—Average number, 121,153. In 1897 much more abundant, averaging 2,170,588. In this year it occurs in numbers above 1,000,000 from the end of July till the end of October, reaching a maximum of 36,000,000 on September 21, 1897. Its optimum conditions occur during the latter part of the period of maximum heat, at temperatures approaching 80°. It disappears at 60°, save for isolated appearances in December, at 33°— a fact which suggests its persistence in small numbers thoughout the year. It is characteristic of the plankton of late summer,—that is, of low water, high temperatures, and stable conditions.

*Ophiocytium capitatum* Wolle*.—Average number, 1,465,385. More abundant in 1897, averaging 2,858,823. Present from the last of April until the beginning of November. There is some indication of a vernal pulse, which on May 25, 1897, attains 3,600,000, and on April 26, 1898, 10,800,000. The major pulse appears in late summer or early autumn, attaining 57,600,000 on September 21, 1897, and 28,800,000 on August 9, 1898. The two pulses are separated by an interval in which occurrences are less frequent and numbers smaller. This planktont thus exhibits the tendency towards seasonal maxima near the average temperature. The greater development in 1897 is followed by a prolongation of the occurrences into November. The optimum temperature appears to be about 60° or above, the vernal pulse appearing at that temperature, and the major one at 71°. No records occur below 46°.

*Pediastrum boryanum* (Turp.) Menegh.—Average number, 4,510. This alga was found in every month of the year, though not in every collection examined. The numbers present fluctuate greatly and are usually much less than those of *P. pertusum*, with which it is associated, and with which it fluctuates, often with remarkable coincidence. I have included under this head those individuals in which the cœnobium is a plate with no intercellular spaces or only insignificant ones. Individuals are not lacking which serve to connect this species with *P. pertusum*, and, indeed, with others which have been described in this genus. This genus includes the most abundant of the larger algæ in the plankton of fresh waters, and it affords an attractive field for the study of variation by statistical methods and for the determination by the experimental method of the effect of environmental changes upon structure. The two groups of individuals included here under *P. boryanum* and *P. pertusum* give typical curves of seasonal distribution which are so similar that their combination in a single series would not greatly modify the resultant seasonal curve. In the sum total of all collections *P. boryanum* (1,034,000) includes about one tenth of the number referred to *P. pertusum* (10,830,117).

A few scattering individuals, generally less than 1,000 per $m^3$., appear at irregular intervals during the colder months, from the first of December until the end of March. The number increases as the temperature rises, and the species appears in all collections until November, when it again becomes irregular in its occurrence in the plankton. The fluctuations in numbers during this period are very marked, the pulses of frequency being set off by intervals in which the numbers are small. A slight pulse of 2,120 appears on November 17, 1894. In 1895 the vernal pulse attains the very unusual number of 572,824 in the unusually low water of that year, and the autumnal pulse of September 5 is but 10,600, and is followed by a secondary one on November 27 of 4,081, perhaps as a result of the stable conditions and the abnormally high temperatures (above 45°) which then prevailed (Pt. I., Pl. IX). In 1896 the vernal pulse culminates May 18 at 31,164, while the autumnal pulse is scarcely visible and the numbers throughout the summer are small, as a result, it may be, of the repeated floods of that year (Pt. I., Pl. X). In 1897, with few vernal data, the vernal pulse does not appear, though a rise to 8,000 occurs on July 21. The major autumnal pulse culminates on September 14 at 14,400, and another one on October 12 at 6,000, attending the late autumn of that year. In 1898 there are vernal pulses—on May 10 of 6,400 and on June 14 of 32,000. The autumnal pulse on September 27 reaches the considerable number of 65,600. In the winter of 1898–99 *Pediastrum* was seemingly absent from the plankton. The pulses are thus somewhat irregular, though there is in this species a suggestion of vernal and autumnal pulses at corresponding temperatures. The optimum conditions seem to lie above 60° and the maximum numbers to occur at or near 70°.

*Pediastrum pertusum* Kütz.—Average number of cœnobia, 44,372. This species appears in the plankton in all months of the year and in almost all of our collections. It is the most abundant representative of the *Chlorophyceæ* which is retained by the silk of the plankton net, and is quantitatively an important factor in the ecology of the plankton. The numbers during the colder months, from November to April, when the water is from 32° to 40°, are few, and the sequence of their appearance is frequently interrupted. As the temperature rises in April the numbers increase, and the vernal pulse culminates in a maximum in May or June. There is no indication of the vernal pulse in the scattered collections of 1894. In 1895 the pulse is extreme, reaching 5,264,860 on June 19, in a period of exceptionally low water. In 1896 a preliminary vernal pulse culminates May 8 at 23,580 and is followed on June 17 by one of 107,200. In 1897 the few spring collections do not reveal any vernal pulse, while in 1898 a minor one on May 17 reaches 5,600, declines to 600 at the end of the month, and rises again to 56,000 by June 21. These vernal maxima all occur—or at least pass through their period of development—before the water reaches its midsummer temperature of approximately 80°. They develop during the transition from 60° to 80° (Pt. I., Pl. IX. to XI.). Autumnal pulses during the decline from 80° to 60° appear on September 5, 1895, (105,996), on September 30, 1896 (9,200), on October 12, 1897 (231,200), and on September 27, 1898 (259,200). In addition to these pulses there are others at irregular intervals during the summer: on July 30, 1894 (154,548), on July 2, 1896 (68,400), on August 15, 1896 (22,000), on July 14 (289,600) and on August 31, 1897 (442,000), and on August 2 (295,200) and 30 (326,400), 1898.

The optimum conditions of development thus lie above 60°, and pulses are more frequent in spring and late summer or early autumn near 70°, though they appear somewhat less frequently during the summer in our maximum temperatures near 80°. The cause of these pulses is not conclusively demonstrable from the data at hand, owing in part to the interval between examinations. Daily examinations of the plankton and chemical analyses seem to be desirable for such demonstration. There are indications, however, that certain conditions in the environment increase the amplitude of the pulses by hastening the rapidity of reproduction of these organisms. Of the fifteen well-defined pulses appearing in our records of six years, all but three minor ones occur in stable conditions, such as pertain to sustained low water. The greater part of these pulses, however, occur in declining floods, when contributions from backwaters are considerable. It may seem ill-advised to refer to the conditions of falling river-levels as "stable"; nevertheless, they are relatively much more stable than those which attend the in-rush of silt-laden flood-waters, and involve fewer changes in factors of the environment. Save in the matter of the relative contributions of backwaters and of sewage dilution they resemble those of sustained low water. These *Pediastrum* pulses are also related to the nitrate pulses (Pt. I., Pl. XLIII.–XLV. and Table X.), but the relation is not uniform. In the majority of instances the pulses of 1896–1898 (during which time chemical anaylses are available) coincide approximately with the crest or decline of increase in nitrates. For example, the pulse noted on July 17, 1896, of 107,200 from a previous level of 1,210 on June 1, follows a wave of nitrates progressing for three weeks and culminating on June 9 at 3.25 parts per million—a rise from 1.5 (Pt. I., Pl. XLIII.). On June 16 the nitrates have fallen again to 2.2, and on the 23d to 2.0, but rise on the 30th to 2.8. *Pediastrum* responds to these changes by dropping from 107,200 on the 17th to 15,000 on the 27th, and by rising again on July 2 to 68,400. Not all of the fluctuations in the two are concomitant. Some of the most marked pulses of *Pediastrum* appear at the lowest levels of the nitrates. For example, that of August 30, 1898, of 326,400, follows no nitrate wave, though it coincides with a reduction in nitrates to the minimum of .05. On the other hand, the nitrites had just passed on August 23, an unusual pulse, to .42, falling again on August 30 to .22 and on September 6 to .05 with the passing of the *Pediastrum* pulse. Pulses of *Pediastrum* are thus apparently not dependent for their development upon an abundance of *nitrates* above the levels shown in the analyses, though a decline in these sources of food or in other forms of nitrogen usually attends these pulses. *Pediastrum* is but one of many factors among the planktonts, and in the environment, biological and chemical, concerned in these changes, and conclusive demonstration of its ecological relations must be obtained by the experimental method. The data here cited are suggestive only; not conclusive.

The relation of *Pediastrum* to the volumetric pulses of the plankton is not a constant one, though there is some correspondence in their fluctuations. The extreme maximum (3,264,800) of June 19, 1895, is coincident with a plankton pulse of 30.42 cm.³, but the number of collections is insufficient to show the relative fluctuations of the plankton and *Pediastrum* at that season. In May and June, 1897, and in October, 1898, the *Pediastrum* pulses culminate shortly after the volumetric pulses. In July and September, 1897, and in August, 1898, they coincide.

*Polyedrium trigonum* Näg.*—Average number, 432,692. Appears from June through September, disappearing when falling temperatures reach 60°. In 1897 it continues through October with the higher temperatures (averaging 65°) of that year. There are slight indications of a September pulse.

*Polyedrium trigonum* forma *minus* Reinsch and var. *tetragonum* (Näg.) Rabh., *P. bifurcatum* Wille, and *P. gracile* Reinsch, were also recorded in a few collections during the period of occurrence of *P. trigonum.* They are all evidently summer planktonts.

*Raphidium polymorphum* Fresen.*—Average number, 21,450,000. Occurs in every month of the year and in a majority of the collections. In 1897 a vernal maximum of 201,600,000 occurs on April 27 and an autumnal one of 28,800,000 on September 21. In 1898 a vernal pulse culminates May 3 at 24,000,000, and thereafter throughout the summer at intervals of three to six weeks there occur five other pulses, the greatest of which culminates July 19 at 75,600,000. A pulse of 90,000,000 on a declining flood in February, 1899, indicates an adaptation on the part of this organism to the whole range of temperatures. A pulse of 25,200,000 December 3, 1896, further illustrates this adaptability. Records in 1897 and 1898, however, suggest that the optimum lies above 60°. It is thus a perennial planktont.

*Raphidium longissimum* B. Schröder.—Appeared sparingly in February, August, October, and December, suggesting that it has also a perennial distribution.

*Richteriella botryoides* (Schmidle) Lemm.*—Average number, 6,399,705 (in 1897). From May to November, with a vernal pulse of 25,200,000 on May 25, and an autumnal one of 100,800,000 on September 21. Optimum temperature about 70°, and disappearing from our records below 60°.

*Scenedesmus bijugatus* (Turp.) Kütz.*—Average number, 155,769. Sparingly from May till the close of September, with slight traces of vernal and autumnal pulses.

*Scenedesmus denticulatus* Lagerh.*—Average number, 86,538. A few occurrences in late summer and early autumn.

*Scenedesmus genuinus* Kirchner.*—Average number, 778,846. From May till the first of October, but continued through this month in 1897. Vernal pulse not observed, though the autumnal pulse attains 28,800,000 on September 21 and October 26, 1897. Midsummer pulses appear in 1897 on July 14 (16,200,000), August 17 (14,400,000), and in 1898 on August 9 (19,800,000). Optimum temperatures lie above 60°, though an occurrence in December indicates the adaptability of this organism to lower temperatures.

*Scenedesmus obliquus* (Turp.) Kütz.*—Average number, 1,505,769 (silk, 673). This form appears in our records from the last of April until the middle of November. Traces of vernal and autumnal pulses appear in both 1897 and 1898, with intervening midsummer fluctuations of even greater magnitude. In 1897 the vernal pulse on May 25 reaches 3,600,000; a midsummer one on August 10, 5,400,000; and the autumnal one appears twice, once on September 21 at 28,800,000, and again on October 19 at 25,200,000. In 1898 the vernal pulse appears May 10 at 1,800,000; midsummer ones, on July 19 at 10,800,000, and August 9 at 36,000,000; and the autumnal on September 9 at 8,100,000. As in some other organisms, these pulses are separated by intervals of three to six weeks. The optimum temperatures lie above 60°, though development begins before that temperature is reached, and the impetus of the autumnal pulse, or acclimatization to lower temperatures, carries the species beyond this limit into temperatures of 45°. There is a marked absence of pulses below 60°. This seems to be a summer planktont with no marked preference for the lower temperatures of spring and autumn.

*Scenedesmus quadricauda* (Turp.) Bréb.*—Average number, 9,276,923 (silk, 8,611). In this species, as in the case of others of the genus and of the *Chlorophyceæ* generally, the numbers present in 1897 were much greater than in 1898 (32,492,647,* silk, 5,818). Prolonged low water and concentration of sewage afforded stable conditions and food requisite for such development. This species appears in our collections in every month of the year, though in much smaller numbers and less frequently from November to April—that is, below 50°. Pulses of noticeable magnitude appear only above this temperature, and usually above 60°.

Slight traces of vernal and autumnal pulses appear in the collections of the silk net in 1894–1896. In the filter-paper collections of 1897–1898 they are well defined. The vernal pulse appears in 1897 on May 25 at 46,800,000, and in 1898 on May 10 at 70,200,000. The autumnal maximum in 1897 is remarkable both for its large numbers and its prolongation, culminating twice—first on September 21 at 151,200,000, and again on October 19 at 154,800,000. This remarkable development, combined with the stable conditions and higher temperatures (Pt. I., Pl. XI.) of that low-water autumn, is responsible for the continuance of the species in our collections throughout the winter. In 1898 the species declined earlier, in November, and was but sparingly represented in collections of the winter of 1898–1899. As in other species of the genus and other *Chlorophyceæ*, midsummer pulses appear at intervals, often of four weeks, but ranging from three to six. In 1897 these occurred on July 14 at 55,800,000 and on August 31 at 21,600,000. In 1898 they appear on June 28 at 10,800,000, on July 19 at 79,200,000, on August 9 at 39,600,000, and on August 30 at 54,000,000. At intervals between the pulses the numbers decrease, and in the regular collections of 1898 the minima between the pulses do not in any case exceed 30 per cent. of the adjacent maxima, and are usually very much less. The distribution of the pulses of this species coincides very closely with that of the other species of the genus, and also with that of other *Chlorophyceæ*. For example, *Pediastrum pertusum*, the most abundant of the larger algæ, has seven of its thirteen pulses on the same dates with those of *Scenedesmus quadricauda* and three others on adjacent dates, leaving but three which are not practically coincident. The operation of some common and general factor in the environment is suggested by such phenomena.

The wide seasonal range of this organism gives it a claim to rank as a perennial planktont, though its quantitative distribution shows clearly that the optimum temperatures for its growth lie above 60°. The largest number recorded in 1897 appears October 19 at a temperature of 65°, and in 1898 on July 19 at 84°. It is thus predominant only during the warmer part of the year; and while autumnal and vernal pulses occur, there is no sustained midsummer minimum intervening between them. The pulses in *Scenedesmus* as a rule *follow* the volumetric pulses as shown in silknet catches (Pt. I., Pl. XI. and XII.). Thus in 1897, on September 14 and 21, the plankton measures 19.8 and 3.0 cm.$^3$ per m.$^3$, respectively, *Scenedesmus quadricauda* numbering 20,700,000 and 151,-200,000; and, again, on October 5 and 19 the plankton measures 12.92 and 1.86 cm.$^3$, and this alga numbers 93,600,000 and 154,-800,000. Its share in the volumetric pulses is thus indirect to a large degree, and is perhaps modified by food relations.

*Schroederia setigera* (Schröder) Lemm.*—Average number, 21,450,000. In 1897, 69,040,912. It appears in all months of the year and in almost every collection. It has well-defined vernal and autumnal pulses separated by the summer period, in which only minor pulses occur. In 1898 midwinter numbers are as high as those of midsummer. *Schroederia* is thus truly a perennial planktont. The vernal pulse appears in 1897 on April 27 at 302,400,000, and in 1898 on May 3 at 150,000,000. The autumnal pulse in 1897 culminates on September 21 at 565,200,000, and is followed by secondary culminations on October 26 at 136,800,000, and on November 23 at 203,400,000. In 1898, when hydrographic conditions were less stable, the autumnal pulse reached only 50,400,000,—on September 6. This is followed by minor pulses, declining to a minimum in the following February. It disappeared in the collections with the flood waters of March, 1899. The sequence of these secondary pulses follows much the same course as has been described for other species, namely, maxima at intervals of approximately a month (two to six weeks) separated by more or less sharply defined minima. There are twelve such pulses (including the major ones) in 1898 and an interval of seven weeks in March–April in which none occurs. Six pulses appear in the last five months of 1897.

The optimum temperatures as indicated by the position of the vernal (60° in both 1897 and 1898, as shown in Table III., Pt. I.) and autumnal (71° in 1897 and 79° in 1898) pulses lie between 60° and 80°. This appearance of the vernal pulse at a lower temperature than the autumnal (usually about 10° lower) is not confined to this species but is a general phenomenon among other *Chlorophyceæ*.

It is apparently a phenomenon of seasonal acclimatization, by virtue of which the low temperatures of the winter lower the optimum for the vernal pulse, and the high temperatures of the summer raise it for the autumnal pulse.

*Selenastrum bibraianum* Reinsch.*—Average number 519,235. Recorded only from the beginning of August till the end of November, and never in great abundance. Slight evidence of a September pulse.

Some other *Chlorophyceæ* have been included in the totals as "unidentified," and isolated occurrences of the following have been noted: *Cerasterias longispina* (Perty) Reinsch, *C. raphidioides* Reinsch, *Dactylococcus infusionum* Näg., *Glœocystis gigas* (Kütz.) Lagerh., *Staurogenia lauterborni* Schmidle, and a few of the *Confervaceæ*—which are probably adventitious. These are a species of *Conferva*, of *Prasiola*, and of *Ulothrix*—all of which appear sparingly in spring and autumn planktons, the first-named and the last as minute filaments in the filter-paper collections. A thorough analysis of the unidentified forms would greatly extend the list of species and varieties.

### BACILLARIACEÆ.

(Plates I. and II.)

Average number, 396,192,716, including, without duplication, diatoms from both silk and filter-paper collections. They were almost twice as abundant in the more stable conditions in which the collections of 1897 were made. The *Bacillariaceæ* are more abundant than any other synthetic group of organisms in our plankton. They exceed (in 1898) the *Schizophyceæ* five to one, the *Chlorophyceæ* seven to one, the desmids eight thousand to one, and the synthetic *Mastigophora* by more than four to one. Their numerical preponderance is, with the exception of the synthetic *Mastigophora*, equaled or exceeded by their relative quantitative significance in the ecology of the plankton.

They appear without exception in every collection, and their seasonal distribution in its main features is repeated from year to year. There is a principal vernal pulse in April–May and a hiemal pulse in November–December. Minimum periods separate these pulses and are varied by other pulses, usually of minor importance, at intervals, in 1898, of three to five weeks. The winter minimum is at a lower level than the summer one. In 1894 the interval of collection is too great to follow the seasonal distribution, but there are hints of summer and autumnal pulses. In 1896 there were no May collections, and the largest number, 6,060,665, appears June 19, five minor pulses—on July 18, August 21, September 12, October 11, and November 5—intervening before the hiemal pulse of 3,574,-028 appears on November 27. Other pulses follow on December 18, January 6, February 4, March 4, and March 17, before the vernal pulse of 1896 culminates at 105,440,858 on April 24. This is followed by minor pulses on May 18, June 11, July 18, August 8, and September 16, and by the hiemal pulse of December 3 of 346,982,-928*. The vernal pulse of 1897 appears April 27 at 6,207,473,520, but is surpassed by a pulse on July 14—principally of *Melosira spinosa*—of 11,459,289,600, and minor pulses then follow on August 17, September 29, October 26, and December 7 and 21. The hiemal pulse of this year is insignificant. In 1898 three minor pulses appear, January 21, February 15, and March 22, and the vernal pulse culminates May 10 at 3,865,257,360. Minor pulses follow on June 14, July 19, August 9, August 30, September 27, October 25, and November 22, and the hiemal pulse culminates December 15 at 436,535,790, followed in 1899 by minor ones on January 10, February 14, and March 14.

Some of the pulses here indicated are due to the development of single species, as that of *Melosira* on July 14, 1897. Most of them, however, are composite, including a number of species. This is especially true of the vernal pulse, which in 1898 is due to the combined increase in *Fragilaria virescens* and *F. crotonensis*, *Cyclotella*, *Asterionella*, *Navicula* spp., and *Synedra acus*. *Asterionella* culminates early in the vernal pulse and the majority of the others towards its close. *Melosira varians* is among these, but *M. spinosa* contributes less to this pulse than it does to later ones. Minor pulses are also composite, as, for example, that of August 9, 1898, which is due to *Melosira spinosa*, *Cyclotella*, and *Navicula*.

FACTORS CONTROLLING DIATOM PRODUCTION.

The fact that many of these pulses represent the combined fluctuations of a number of species leads us to look for some factor

* Filter-paper collections included in this and in following years.

in the environment common to them all to which these pulses may be attributed. On the following page the seasonal distribution of the total diatoms has been plotted for 1898, along with that of the nitrates and of the total plankton (volumetric), the thermograph, and the hydrograph. An examination of the changes in nitrates yields no marked evidences of correlation. The vernal pulse of diatoms follows the high nitrates of winter and spring, and the hiemal pulse in December appears after their autumnal rise, and in this particular year develops at the time of an unusual drop in nitrates (Pt. I., Pl. XLV.). The diatom pulses do not show any constant relation to the movement in nitrates either in amount or direction. Whipple ('94) has noted the importance of nitrates in the development of diatoms in reservoir waters. The fact that little correlation *appears* in our waters between the fluctuations of the nitrates and the growth of diatoms may be due to the presence here of nitrates —owing to sewage contamination—far in excess of the demands which the diatoms make, and the limitations placed by other elements in the environment are reached before that of the nitrate food-supply becomes operative. The distribution of these diatom pulses throughout the whole year, even in seasonal extremes, seems to preclude the factor of temperature as the immediate cause of the pulses except as it may affect the growth of individual species, which is sometimes apparently the case, as is shown in subsequent pages.

The vernal pulse is attained each year about May 1, at which time the water passes the temperature of 60°. The average of the recorded surface temperatures of 1898 in the river is about 58°. Surface temperatures, except in winter months, are usually several degrees higher than bottom temperatures (Pt. I., Table III.). Our records are always of diurnal temperatures. The true average temperature, owing to colder water at lower levels and to the nocturnal decline, will lie several degrees below 58°—probably about 55°. The greatest development of diatoms thus takes place at a temperature a few degrees higher than the average temperature for the year. Owing to the somewhat greater abundance of diatoms during the warmer months, the average thermal exposure of the plankton diatoms will be somewhat higher than the average temperature of the year. There may be some significance in this phenomenon of the occurrence of the optimum temperature for development at

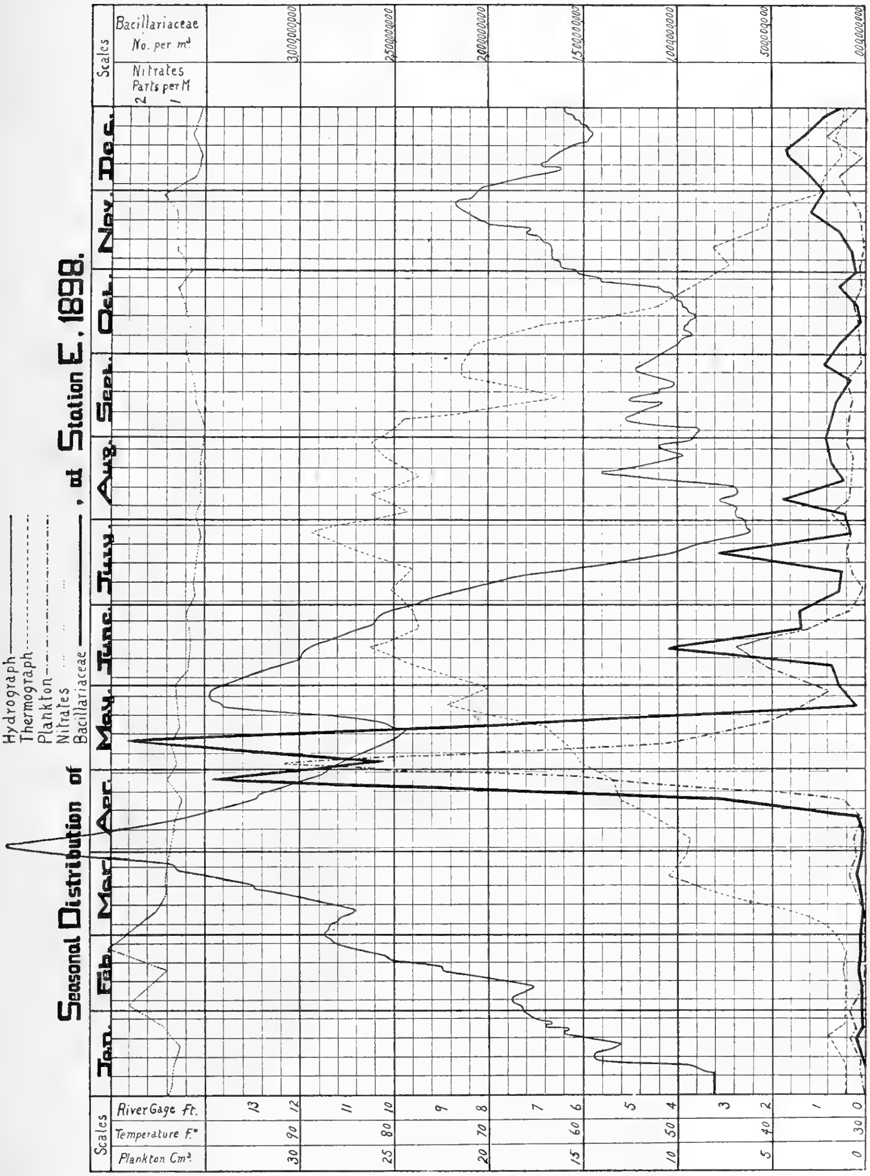



Fig. A.—Diagram showing the seasonal distribution of diatoms, total plankton, nitrates, and thermograph and hydrograph of Illinois River at Havana for 1898.

approximately that of the average thermal exposure. The vernal pulse may, in part at least, be the result of a process of natural acclimatization. The fact that a similar development does not recur when this temperature is repassed in the autumnal decline militates, it is true, against the potency of this temperature as a factor in the vernal pulse. This temperature is passed in October (Pt. I., Pl. VIII.–XIII.), but October pulses are rarely so pronounced as those of adjacent months. Other factors more potent than temperature are operative at that season of the year.

As will be seen in the diagram, the most pronounced and prolonged minimum appears in January, February, and March. In these months but a single record in excess of 100,000,000 per $m.^3$ is found. This—or at least the first two months of it—is the period of the ice blockade (Pt. I., Pl. IX.–XIII.), during which the aeration of the water by the wind is prevented, and the customary equilibrium in gaseous contents may be disturbed. It is the time when stagnation most threatens disaster to the plankton. The earlier stages of this blockade in December do not seem to be deleterious to the growth of diatoms, since at such times the blockade is less complete, the exclusion of light by the ice less effective, and the accumulation of the products of decay less pronounced. The data at hand do not suffice to elucidate the matter further.

The position of the diatom pulses with respect to the movement of the hydrograph is suggestive—though not conclusive—of a possible correlation between the two phenomena. The double vernal pulse of April–May appears in the declining waters of the major spring flood. The diatom pulse of June 14 is found in the decline of the May–June flood. The pulse of August 9 is caught on the rising waters of a slight flush of the river, and that of August 30 on its decline. That of September 27 appears after a series of slight rises, and those of both October and November attend rising water, but the well-developed pulse of December appears with its decline.

There are, counting the double vernal pulse, ten pulses in 1898, from March to January. Of these, seven are found on declining floods, and but three on rising water, and two of these three appear during the slow rise of October–November. Furthermore, the magnitude of the flood is correlated with that of the diatom pulse. The vernal pulses of 3,453,778,080 and 3,865,257,360 attend the major spring flood, culminating April 2 at 18 feet; the pulse next in size, that on June 14 of 1,039,619,680, attends the decline of the flood next in importance—that culminating May 25 at 13.9 feet; while the third pulse, that on December 15 of 436,535,790, attends the decline of the flood culminating November 25 at 8.7 feet. The hydrograph of 1897 (Pt. I., Pl. XI.) is unlike that of 1898 (Pt. I., Pl. XII.) in the delay of the so-called "June" rise, which culminates July 5 at 7.5 feet. Its decline runs through the month into August. The diatom pulse attending the "June" rise of 1897 appears about a month later than it did with the earlier pulse of 1898, culminating July 14 at 11,459,289,600. A delay in the flood is thus attended by a delay in the diatom pulse. In 1897 there is no December rise and no diatom pulse of noticeable magnitude, though in 1895, in similar absence of the flood, there is a well-defined diatom pulse. In 1896 there is a series of five floods, each involving the early stages of overflow (Pt. I., Pl. X.), and on the decline of each occur one or more diatom pulses.

It is but natural that the greater number of diatom pulses should fall on declining river-levels, since, as I have previously shown, these periods exceed in duration those of rising floods. They also predominate during the prevalence of seemingly favorable temperatures, and are characterized by relatively more stable conditions in the environment. There is, however, it seems to me, another and more potent reason why diatom pulses appear at such times. It lies in the overflow of seed-beds in the margins of the permanent backwaters and the run-off of the plankton which develops there with the fall in levels. This is very apparent to one familiar with the locality. During the decline of the flood the channel current is often diverted in minor lateral channels, such, for example, as that (Pt. I., Pl. II.) which courses through Thompson's Lake Slough into Thompson's Lake and out again into the river at its southern end by way of "the swale" and the "cut road." A similar current on the eastern bottoms, which enters partially by way of Mud Lake Slough, rejoins the river through Quiver Lake. These lateral currents are joined by the run-off from overflowed bottoms and adjacent marshes and swamps, all of which, as well as the permanent backwaters thus draining into the channel, breed at such times an abundant plankton including diatoms. The contributory function of the backwaters to the plankton of the river proper is thus at its maximum during the *decline of the flood.*

As the flood recedes, relict pools on the bottom-lands and along the margins of the permanent backwaters are formed, in which the conditions favoring sporulation or other means of providing for resuscitation are to be found. The emerging bottom-lands thus become the seed-bed for starting a new cycle of diatoms whenever flood conditions return. In the river, on the other hand, the conditions for sporulation are not so favorable, and the current tends to carry away such resting stages as may be formed. The observed facts regarding the distribution of diatoms and the examination of the conditions under which these pulses occur thus alike yield corroboration of the view that *floods are potent factors in determining the occurrence of diatoms in fluviatile waters*, especially where backwaters are extensive.

The nature of the action of floods is in some respects similar to that of the overturning of the water which occurs in lakes when the point of maximum density, 39.2°, is passed in either direction. In lakes of some depth the vertical circulation of so large a volume of water results in a stirring up of the bottom deposits containing the resting stages of diatoms, so that they are brought again into increased light and to better aeration. Whipple ('94) has emphasized the importance of this overturning in starting the growth of diatoms. In our shallow waters this physical phenomenon is of less importance than in the deeper waters of the lake or reservoir. The volume in circulation is smaller, though some compensation for this may exist in the possibility of repeated overturnings with fluctuations in temperatures at the critical stage. The existence of currents, the movements of fish, and the roiling effect of strong and long-continued winds upon our shallow backwaters, combined with the fact that much of the seed-bed area of overflow is dry land at the time of the autumnal overturning, all serve to minimize the effect of this overturning in our waters upon the growth of diatoms in the plankton. The spring overturning occurs early in March, and in 1896, 1898, and 1899 a slight pulse not exceeding an increase of 100 per cent. follows the overturning within an interval of a fortnight. The vernal pulse is about two months later than the overturning, and the relation of this to the overturning does not seem to be intimate. The autumnal overturning occurs towards the middle or end of November, and in 1895, 1896, and 1898 the hiemal pulse of December follows close upon it, within two, or at most three, weeks.

The relation is here more apparent, but the resulting pulse is no larger than those following upon floods during summer, and but little larger than the ones which precede it in the autumn. The effect of this overturning upon the plankton of the Illinois River may thus be detected, though it is here of less importance than in lakes and reservoirs since it is overshadowed or replaced by other and more potent factors.

The relation of the seasonal distribution of the diatoms to that of the total plankton is not readily unraveled. The latter is the resultant of a most complex series of factors, whose number and relative potency are subject to constant change and readjustment in the unstable environment of the stream. It is the biological expression of the state of tension among these various factors which for the moment exists. Of these factors the diatoms are but one, though an important one, in the food cycle and ecology of the plankton. The volumetric determinations in the diagram (p. 37) do not give the true seasonal distribution of the total plankton owing to the escape of an unknown quantity through the meshes of the silk net. They represent more truly that of the animal plankton than that of the phytoplankton. A comparison of the seasonal distribution of the diatoms and total plankton may serve, in spite of the errors involved in the volumetric determinations and the disparity of individuals among the diatoms, to throw some light on the effect of the fluctuations of the latter upon the movement in the volume of plankton. A close comparison of the two seasonal curves reveals the fact that the diatom curve is not identical with the volumetric curve. It is true that the double vernal (April–May) pulse of diatoms coincides in location with the vernal volumetric pulse. This is also true of the pulses of June 14 and July 19. The crest of the volumetric vernal pulse is, however, lodged between the double apices of the diatom curve, and all the subsequent volumetric pulses from July on lie in depressions of the diatom curve, and vice versa. It is apparent at once on examination of our planktons that the catches of the silk net are from the volumetric standpoint largely, indeed overwhelmingly, of animal origin. These volumetric pulses are as a rule largely pulses of the zoöplankton. It is therefore to be expected that the diatoms would decrease at such times, since they form the food of many *Entomostraca* and not a few *Rotifera*. The appearance of the diatom pulses before or after the volumetric (animal) pulse may therefore in a measure present the wavering tendency to establish an equilibrium between these two elements of the plankton. The presence of an abundant animal plankton may therefore be a cause of some of the minimum periods between diatom pulses. Other causes, such as decline of food elements, may also arise, but in our waters the nitrates at least rarely ever reach a level where an unutilized margin capable of supporting a large diatom population is not still present. Data concerning other food elements are not at hand, but their paucity in water derived from such varied sources and so liberally fertilized by organic wastes seems improbable. There is also the further possibility—and, indeed, from the data in hand the probability—of the existence among diatoms of reproductive cycles, interrupted by resting periods. The available data do not, however, throw any light upon the nature of this internal factor or the cause for the running down of the energy of reproduction, and but little upon the operation of environmental factors which stimulate anew the process of reproduction.

The seasonal distribution of the diatoms as a whole, and that of individual species also, offer repeated instances of recurrent pulses at intervals approximating four weeks—the lunar month. In 1898 thirteen such pulses can be detected. These often correspond roughly to minor flood intervals, but not always so, for occasionally two pulses occur on the decline of a single flood. Similar appearances may be traced in other years, when collections were frequent enough to exhibit minor pulses. They are, however, in all cases quite irregular, and exceptions are frequent.

That cosmic factors may indirectly, *through immediately environing factors*, affect the reproductive phenomena of pelagic organisms has been suggested by the work of Krämer ('97), Mayer ('00), and Friedländer ('01) in the case of the "Palolo" worm, a coral-reef annelid whose seasonal swarming for reproductive purposes occurs at somewhat definite lunar intervals.

While the data concerning the seasonal distribution of diatoms in the Illinois River may serve to suggest the operation of an enigmatic cosmic factor, I wish distinctly to state that in my opinion they are *wholly inadequate to establish* either its presence or its potency. It is much more probable that we have to deal merely with some matter of food relations between the plants and animals of the plankton, and perhaps with the result of increased photosynthesis in periods of lunar illumination, which tends to establish the limits of the pulses.

The number of forms of diatoms noted in our records in the plankton of the Illinois River is thirty-one. This number could be greatly increased by the inclusion of the many adventitious species which flood-waters bring into the plankton and by the addition of rarer limnetic species. Of these thirty-one at least twelve are eulimnetic, while the others are in the main adventitious. There are no species among them peculiar to the potamoplankton, and the dominant forms here are also abundant in the fresh-water plankton of our own Great Lakes and of European streams and lakes, barring a few mooted points of specific identity.

The limnetic species are fourteen in number, viz.: *Asterionella formosa*, *A. gracillima*, *Cyclotella kuetzingiana*, *Diatoma elongatum* var. *tenue*, *Fragilaria crotonensis*, *F. virescens*, *Melosira granulata* var. *spinosa*, *M. varians*, *Meridion circulare*, *Rhizosolenia eriensis*, *Stephanodiscus niagaræ*, *Synedra acus*, *S. acus* var. *delicatissima*, and *Tabellaria fenestrata*. Of these limnetic forms the more important ones are *Asterionella gracillima*, *Cyclotella*, *Fragilaria virescens*, *Melosira granulata* var. *spinosa*, and *Synedra acus* and its varieties. The absence or small number of certain limnetic species is noticeable. These are several species of *Tabellaria* and *Attheya*. On account of the abundance of silt and the transparency of *Attheya* it may have been overlooked. It has hitherto been reported from waters much nearer the sea, and this coupled with its affinities to marine diatoms may explain its absence in our waters.

The remainder of the forms are adventitious, or largely so, and with the exception of the species of *Navicula* they have little effect upon the ecology or quantity of the potamoplankton.

### DISCUSSION OF SPECIES OF BACILLARIACEÆ.

*Asterionella formosa* Hassall.—Average number of individual cells, 960. Average size of colony, 4.8 cells. Recorded only in November, December, and from February through April, and never in large numbers. The greatest pulse attained at any time culminated on March 30, 1896, at 54,540. Aside from an isolated occurrence on June 27, 1896, no individuals were recorded at temperatures above 48°, and three fourths of the occurrences are at temperatures below 40°. The data are insufficient to trace the pulses satisfactorily. This species is distinguished with difficulty from *A. gracillima*, and may include only old, and in our planktons often heavily incrusted, individuals; or it may be only a low-temperature variety of the species above named, which in the grand total of all our collections outnumbers it ten thousand to one.

*Asterionella gracillima* Heib.—Average number of individual cells, 28,860,160. In 1897 the species was only one third as abundant, a contrast which finds its explanation in the fact that the June rise of that year (Pt. I., Pl. XI.) did not reach the stage of overflow, and a June pulse is absent in the collections of that year. The seasonal distribution of this organism is one of the best-defined and most striking of all the components of the river plankton. It is peculiar in the fact that it appears in numbers only during spring and the beginning of summer, and in the absence of any autumnal pulse upon the return of the temperatures in which the spring pulse appeared. This species was recorded in every month of the year but October, but always in small numbers after July 1. In 1894, collections were not commenced until after the time of the spring pulse. In 1895 the spring collections were few, and at intervals so great as to preclude the detection of the full course of the spring pulse. The maximum number in the collections of that year appears April 9 at 1,203,100 and falls to 445,995 on April 29—which is approximately the time of the maximum of subsequent years. This was a year of unusually low water during the spring, and overflow stage was at no time reached (Pt. I., Pl. IX.), which may account for the apparent suppression of the spring pulse. The species does not reappear in the collections of that year until December, but it continues in small numbers (less than 5,000 per $m.^3$) until the end of March, 1896, when there is a rapid increase which culminates April 24 at 26,281,400. It disappears entirely from the records at the end of a fortnight, and save for a single entry in June and two in September it does not again appear in 1896. In 1897 the culmination of the spring pulse occurs April 27 at 324,633,600—three hundred-fold larger than in the previous year. There is a normal March flood (Pt. I., Pl. XI.), on the declining stages of which this pulse appears. With the close of June the species disappears from the records. The June rise does not reach the stage of overflow, and the scanty records show but this single pulse throughout the year. Beyond a single entry in August and in

November the species does not again appear in the records during the year. In 1898 there is an unusual midwinter pulse on January 11 of 146,280, followed by a decline and irregularities due to the rising winter flood (Pt. I., Pl. XII.). At the middle of March a rapid increase ensues, culminating April 26 at 891,648,000 on the declining spring flood. A decline to 197,683,200 is found at the close of a week, and it is accelerated by the secondary spring flood, which attains the overflow stage of 15 feet in the closing days of May (Pt. I., Pl. XII.). With the decline of this flood in June a second pulse appears, increasing from 15,080 on May 26 to 336,194,880 on June 14, and at the end of three weeks the species practically disappears from the plankton. A few scattered entries appear during the summer and fall, and a minor pulse of 10,500 appears on December 20, followed by a decline in the next month.

This species in our waters exhibits a well-defined vernal pulse towards the end of April at about 60°, but no autumnal pulse appears when this temperature recurs. There is a slight indication of a minor midwinter pulse at the minimum temperatures of the year. This occurrence of a midwinter pulse was noted by Whipple and Jackson ('99) in the reservoirs of the Brooklyn water-works, and in the same paper its seasonal distribution in Fresh Pond, Lake Cochituate, and Wenham Lake, Massachusetts, is given for the years 1890–97, in the majority of which a midwinter pulse commensurate in magnitude with the vernal pulse is to be found. Autumnal pulses are of infrequent occurrence, the vernal pulse being the most frequent but not constant. In European waters no such long-continued examination of the seasonal distribution of this organism has as yet been reported. Apstein ('96) finds two pulses per year in Plöner See—in May and the last of July; and two in Dobersdorfer See, one in April and one in October, separated by midsummer and midwinter minima. Lauterborn ('93) finds that this species in the "Altwasser" of the Rhine attains its maximum in June and again increases in October. In the backwaters of the Elbe, Schorler ('00) reports *Asterionella* as abundant in April, June, July, and October, but refers the organisms to the preceding species. The existence of the vernal pulse only in our waters is thus somewhat unique, and the cause of the phenomenon probably lies in some environmental conditions, perhaps in our peculiar bacterial and sewage contamination of the autumn. Our vernal pulses appear on declining floods about the end of April at about 60°. It can not be temperature which limits the occurrence of the species, for this apparent optimum recurs again in October. This is the period of declining nitrates (Pt. I., Pl. XLIII.–XLV.), but they rise again in the autumn, and in our sewage-fed waters they contain even in the midsummer minimum a quantity adequate to support an abundant growth of *Asterionella*. Whipple and Jackson ('99) have found on analysis that *Asterionella* to the number of 10,000,000,000 per cubic meter yield but .079 parts per million of organic nitrogen. The nitrates in our waters rarely fall below .25 parts per million, which, with the other forms of nitrogen that may be available, would seem to afford nurture not only for *Asterionella* but also for competing organisms. These authors have also found that silica to the amount of 1.78 and manganic oxide to .03 per million are contained in *Asterionella* to the number per cubic meter above quoted. As was shown in Pt. I., p. 234, the silica is present in great excess (26 to 81 parts), and the manganic oxide, though not reported in the analyses of November waters, is present on June 15 to the amount of .07 parts per million—more than double the amount required to support *Asterionella* to a maximum twelve times as great as any recorded in our plankton collections. This also occurs at a season when *Asterionella* is usually declining rapidly in numbers. Such chemical data as are available thus afford us no explanation of the limitation of *Asterionella* in our waters to the vernal pulse alone.

Some evidence bearing on a factor which may be operative in producing this phenomenon is to be found in the hydrographic conditions attending the vernal pulse. As previously noted, this appears each year with the decline of the spring flood. A repetition of the overflow in 1898 at the end of May brought with it a repetition of the vernal pulse of *Asterionella* in early June. With the decline of the flood the backwaters make their major contribution to the channel plankton, and it is during this period that *Asterionella* reaches its maximum and also declines. If the spring flood is suppressed, as in 1895 and 1896, the spring pulse of *Asterionella* is correspondingly feeble. The environmental conditions are thus more favorable in the impounded backwaters than in the main stream. Whipple and Jackson ('99) have noted in frustules of this diatom the appearance of structures which they interpret as spores. If these are spores, and if the sedimentation of spore-bearing frustules occurs extensively in the relict pools of the emerging bottom-lands, a seed-bed for re-stocking the waters of overflow is formed with each declining flood, and this seed-bed becomes potent only when floods return. The absence of an autumnal overflow and the minor part that the autumnal overturning plays in our shallow waters when 39.2° is passed, may alike tend to suppress here the autumnal or midwinter pulses which occur elsewhere in deeper water.

The occurrence of the vernal pulse of *Asterionella* in the last days of April brings it into close relation with the major volumetric pulse of the year (Pt. I., Pl. IX.–XII.). It is not only an important constituent of this spring maximum, but it is one of the most prominent primal sources of food of the *Entomostraca—Bosmina*, *Daphnia*, *Cyclops*, and *Diaptomus*, all of which exhibit an increase in numbers at this period. It shares with *Cyclotella* the claim to the first place quantitatively among the synthetic organisms upon which the early spring plankton depends for its development.

Our records are all based upon the catches of the silk net, through whose meshes the isolated cells of *Asterionella* readily escape. Filter-paper catches give much higher numbers except during the period of maximum, when the numbers by the two methods do not materially differ. This seems to be due to the fact that isolated cells are relatively much more abundant after the maxima than they are before them, and especially at the time of their appearance. These diatoms form arcs, circles, or whorls, of a varying number of cells. During the vernal pulses of 1898 the average number in these clusters in the middle of March was three or four, and at the time of the maximum on April 26 it rose to five or six, often reaching sixteen or more. A fortnight after this maximum the average fell to 1.4, rising again with the second pulse, on June 14, to 8.4, and declining in three weeks, with the fading out of the pulse, to 1.2.

*Asterionella* is frequently infested with great numbers of a minute craspemonad flagellate protozoan which appears in thick-set rows upon the ray-like cells, a single cell sometimes bearing a score of these organisms. This diatom exhibits considerable variation in size and proportions. The longer and more slender cells appear at the times of the maxima.

*Cocconeis communis* Heib.*—Average number, 520,000, but more than three times as abundant in 1897. This diatom occurs somewhat irregularly in the filter-paper collections, and has been recorded in every month of the year. It is somewhat more prevalent in spring and autumn, and there are indications of a vernal pulse in May and an autumnal one in September, separated by prolonged midsummer and midwinter minima. Vernal pulses appear in 1897 on June 28 at 14,400,000, and in 1898 on May 17 at 7,200,000. Autumnal pulses occur in 1896 on September 16 at 2,700,000; in 1897 on September 29 at 10,800,000; and in 1898 on September 13 at 5,400,000. The optimum temperatures lie between 60° and 75°, the autumnal pulse appearing in higher temperatures than the vernal as a rule. This diatom is reported as often epiphytic upon algæ, and it may be wholly adventitious in the plankton. There is nothing, however, in the curve of its distribution to corroborate this view.

*Cyclotella kuetzingiana* Thw.*—Average number 243,659,615, but slightly more abundant in the preceding year. This is one of the smallest as well as one of the most abundant of all the diatoms of the river plankton. It readily escapes through the meshes of the silk net, and plankton collections made by this means give no adequate conception of its prevalence or importance in the ecology of the plankton. It appears in every month in the year and in practically all of our collections, and is thus a perennial planktont. There is a considerable variation in size among the individuals in the plankton, but the greater number lie near the smaller rather than the larger limits. It may be that several species have been combined in the enumeration.

The fluctuations in the seasonal distribution of this diatom are considerable, and pulses occur at all seasons of the year. The vernal pulse is, however, preëminent, and is not approached in magnitude by those of any other season of the year. In 1897 this pulse culminates at 5,724,000,000 on April 27, and in 1898 on April 26 at 2,880,000,000. Throughout the summer and autumn in both years there is a series of minor pulses at intervals of two to eight weeks. In 1897 an autumnal pulse of 223,200,000 appears on September 29, and though not of greater magnitude than two previous summer pulses, it does surpass anything prior to the pulse of the following spring. In 1898 there are seven pulses during the summer and fall, culminating as follows: on May 10 at 2,668,000,000; on June 28 at 291,000,000; on July 19 at 561,600,000; on August 9 at 401,400,000; on August 23 at 122,400,000; on September 6 at 115,200,000; on September 27 at 57,600,000; on October 25 at 25,200,000; and in December a pulse well sustained throughout the month culminates on the 15th at 414,000,000.

The temperature optimum appears to be about 60°, though its return in the autumn does not induce a development comparable with that of the closing days of April. The midsummer pulses and that of December show that other causes than temperature are operative in regulating the occurrence of this organism.

The appearance of the vernal pulse of *Cyclotella* at the time of the volumetric maximum (Pt. I., Pl. IX.–XII.) in April–May suggests its function as one of the primal sources of food for the animal components of that plankton. The plates are based on collections of the silk net, and *Cyclotella* constitutes an insignificant part of the volumetric total there graphically presented, since it is so small that it escapes readily through the silk.

*Cymatopleura solea* (Bréb.) W. Sm.*—Average number, 2,115 (silk, 1,292), but slightly more abundant in 1897. Isolated occurrences in small numbers appear during the colder months, generally below 60°, though several individuals appear in summer records. This is apparently an adventitious planktont, whose presence is often due to flood waters.

*Diatoma elongatum* var. *tenue* Van Heurck.*—Average number, 2,471,923. This is a perennial limnetic diatom occurring in every month of the year and in the majority of our collections. It is but sparingly present during midsummer. There are well-defined vernal pulses in 1897 on May 25 of 50,400,000, and in 1898 on May 3 of 18,000,000. A second large pulse appears on the approach of winter, in 1897, on November 15, culminating at 2,700,000, and in 1898, on November 22, at 9,000,000. In the silk collections of 1895 and 1896 pulses also appear in the last days of April and in November or December. The records thus indicate a decided preference of the species for temperatures below 70° and the possibility of rapid development in midwinter—as in 1895, during a fortnight of minimum temperatures (32°+), culminating at 53,424 (silk) December 18. The vernal pulses coincide approximately with the volumetric maximum, and the December pulse of 1895 attends an unusual winter development of the plankton (Pt. I., Pl. IX. and Table III.).

*Diatoma vulgare* Bory occurred sparingly at irregular intervals, and is apparently an adventitious species in the plankton.

*Encyonema prostratum* (Berk.) Ralfs appears a few times during the summer months, and is evidently adventitious, as is also the still rarer *Epithemia turgida* Kütz.

*Fragilaria crotonensis* (Edw.) Kitton.—Average number of cells, 2.1. This limnetic diatom is much less abundant in our waters than the following species. In 1898 it appeared in February, and increased from 19,200 on April 19, to 14,469,120 on May 10, disappearing entirely from the records after May 17. Such meteoric pulses were not detected in previous years, when only scattered entries in April, May, and December were recorded. The number of cells in the filaments is very much less than in *F. virescens*, averaging but 14 to its 108. Its optimum temperature lies about 60°, and its vernal pulse occurs immediately after the volumetric maximum (Pt. I., Pl. XII.) and upon the same date with that of *F. virescens*. It seems to be predominantly a vernal planktont in our waters. In German lakes Apstein ('96) finds maxima as late as June–July, but always, it seems, at temperatures below 70°.

*Fragilaria virescens* Ralfs.—Average number, 73.1. Apparently ten times more abundant than in 1897, as a result possibly of the absence of collections during the period of the vernal maximum in that year. This is a perennial organism, with two well-defined pulses; a vernal one in April–May and another in November–December. The uniformity with which these pulses appeared in 1895–1898 is very striking when one considers the unstable environment in which the pulses occur. In 1894 the species is not present in numbers in any of the scattered collections of the year. In 1895 the vernal pulse is indicated in the collection of April 29 (2,754,675), after which the species disappears until September, increasing—with a temporary backset by the December flood (Pt. I., Pl. IX.)—to a second culmination December 30 at 282,225. After a minimum in January, 1896, the numbers increase, with minor fluctuations, to a vernal maximum of 76,224,000 on April 24, followed by a minimum period from May 18 to the following November. The winter pulse again appears in December, culminating on the 3d at 867,048. In 1897 the vernal pulse seems to culminate somewhat later than usual, though the interval of collection is too great to follow its full course. The maximum appears on May 25 at 3,549,600, after which the species dwindles away and disappears in August to return early in November. The winter pulse culminates December 14 at 8,159,250, at a break in the ice blockade. In 1898 the winter minimum continues into April, and the vernal pulse appears May 10 at 253,960,000, rising with rocket-like suddenness from 390,000 of the previous week, and declining the week following to 4,110,400. The decline to the summer minimum is prolonged into July, and the species does not reappear until October. The winter pulse begins earlier than usual, on November 1, and is well sustained through the month, culminating on the 29th at 2,254,000. The winter minimum which follows, does not reach the low levels of that of summer.

This species has thus a characteristic distribution, the analysis of which is by no means simple. The contrast between the summer and winter minimum may be due to the low nitrates of the summer and the larger amount in the winter (Pt. I., Pl. XLIII.–XLV.), which favor a proportionate development of this diatom, though not every species shows this response. The two minima separate the seasonal occurrences of this species into two periods of growth; a vernal, from March to June, and a hiemal, from October to January, the limits and relative development of each being somewhat variable from year to year. The temperatures of the two periods differ. Both are times of rapid change,—of rise and fall respectively,—and the culminations of the periods of growth lie at widely separated temperatures. The vernal pulses in 1896 and 1898—in which years collections were frequent enough to locate them with some degree of accuracy—appear at 72° (April 24) and 61° (May 10) respectively, and in every year the vernal pulse appears during a period of rapid change. The hiemal pulse, on the other hand, culminates in each year after the winter minimum approaching 32° has been reached, and in two years during the ice blockade. Temperature within these limits seems not to be a determining factor in the pulses of this organism. The nitrates (Pt. I., Pl. XLIII.–XLV.) have been uniformly high (above 2 parts per million) whenever the pulses occurred. In 1898 they decline abruptly (Pt. I., Pl. XLV) and remain at a low level throughout December, and in this month, when usually *Fragilaria* attains its hiemal maximum, we find it dropping to the unusual minimum of 20,000. The pulse which began in November is cut off apparently by this unusual decline in nitrates. Abundance in nitrates is not, however, in itself sufficient to cause a pulse of development of *Fragilaria*, for nitrates are abundant when the diatom declines and is at its minimum. It does not seem possible to find in the unstable environment of this organism any external factor which shows a causal connection with its periods of growth.

Apstein ('96) found that this diatom reached its major pulse in March and April in Dobersdorfer See, and a minor one in November.

The cells of this diatom form long twisted bands, visible to the unaided eye. They reach a much greater length in this species than in the preceding one, and are longest during the height of the growing period, decreasing rapidly in length as it declines. The average number of cells in a ribbon at the time of the maximum lies between 150 and 200, and at other times is usually below 100 and often below 25.

The vernal pulse of this species coincides with that of *F. crotonensis*, and appears either with or just after the volumetric pulse. The December pulses may in part serve as primal food sources for the fairly constant minor volumetric pulse of December.

*Gomphonema constrictum* Ehrbg.*—Average number, 501,923. This species appears irregularly, with a predominance of occurrences in May and November, and is apparently adventitious.

*Melosira granulata* (Ehrbg.) Ralfs var. *spinosa* Schröder. —Average number of cells, 1,181,125 (filter-paper, 34,762,365). In 1897 it was more than five times as abundant. In the filter-paper collections as a whole it is about fifty times as abundant as in those of the silk net. A much greater proportion of single cells and short filaments occurs in the latter collections, since the longer filaments are the more readily retained by the silk. In the discussion which follows, the data from the silk collections will be used, since they cover the whole period. The data from the filter-paper collections indicate very nearly the same seasonal routine, and the differences between the results by the two methods lie in the proportions of the numbers rather than in the direction of movement in the fluctuations. The pictures of the seasonal changes in occurrence of the diatom given by the two methods are essentially alike aside from greater irregularity during minimum periods, resulting from the larger margin of error in the filter-paper method as I used it.

This *Melosira* is a perennial planktont in that it occurs in every month of the year in the river. Its appearances from December to March are, however, irregular, and its numbers small. Its large pulses—above 1,000,000—all lie between May 15 and October 1, with the single exception of the pulse of April 24, 1896, culminating at 2,056,400, in temperatures of 72°, occurring fully a fortnight earlier than usual. The major pulse seems normally to occur in June; at least in 1896 and 1898, when collections were frequent at this season of the year, such pulses appear on the 11th at 12,940,000 and on the 21st at 32,114,880. A June pulse also appears in 1895. September pulses appear in 1895, on the 12th, at 2,254,182, and in 1898, on the 27th, at 5,499,840. There is, however, no well-defined vernal and autumnal growth period, since large pulses occur throughout the whole summer. The greatest pulse on record (111,456,000) is on July 21, 1897, and in 1898 there are three minor pulses between those of June and September. Including the major pulses, there are in 1895 five, in 1896 six, in 1897 five, and in 1898 eight, pulses at intervals of two to six weeks between May and October, the ones at either end of the season being often but slightly developed, the remainder usually running from 1,000,000 to 5,000,000.

This species is predominantly a summer planktont, and its optimum temperature lies above 70°, the greatest number recorded appearing at 81°. This is one of the most abundant diatoms of the potamoplankton, and in our waters it attains its greatest development during the season of the minimum occurrence of nitrates, in whose utilization it is quantitatively an important agent. It fills the gap between the vernal and autumnal or hiemal appearances of *Asterionella* and *Fragilaria*, thus providing a continuous source of food for the zoöplankton with which it is associated. It is, by virtue of its numbers, its size, and its seasonal distribution, quantitatively and ecologically the most important of all the diatoms of the plankton of the Illinois River.

The only factor in the environment to which the limitation of the rapid growth of this species to the May–October period can be referred is temperature. There are but three instances in the records of *Melosira* exceeding 100,000 per $m.^3$ at temperatures below 60°, and one of these is but a few days prior to the attainment of that temperature. It cannot be food which deters its development below this point, since the nitrates at least are then most abundant (Pt. I., Pl.

XLIII.–L.). Other diatoms, as in the hiemal pulse of *Fragilaria*, develop in numbers at temperatures approaching 32°, but not *M. granulata* var. *spinosa*. Whipple ('94) concludes from the records of examinations of potable waters in Massachusetts that temperature has possibly a slight influence on the growth of diatoms, but that it is of so little importance that it does not affect their seasonal distribution; and, on the other hand, that a sufficient supply of nitrates is one of the most important conditions for their growth. The seasonal distribution of *Melosira* was not separately discussed in his paper though included in his general statements. In our waters the data at hand seem to show conclusively that abundance of nitrates is of no avail in the case of *Melosira* when the temperature falls below 60°. There are times, therefore, in the case of this, our most important diatom, when temperature is more potent than food as a factor controlling its growth.

*Melosira* does not appear in its maximum pulses at the time of the major volumetric pulse of the total plankton of April–May, nor do its fluctuations seem to bring about directly any considerable changes in the volume of the plankton. For example, the extreme pulse of 111,456,000 on July 21, 1897, occurs at the time of a sudden drop in the amount of plankton (Pt. I., Pl. XI.). The amount of plankton on July 14, 21, and 30 is 8.16, 0.92, and 1.05 $cm.^3$ per $m.^3$, and the corresponding numbers of *Melosira* are 66,528,000, 111,456,-000, and 13,176,000.

The diatoms here discussed are predominantly of the type designated as var. *spinosa*, marked by the spinous prolongations from the valves at the ends of the filaments. The cells of the forms in our plankton are proportionately much longer, as a rule, than those figured by Schröder ('97), usually attaining one and a half to two times the length without proportional increase in diameter. Not infrequently in the height of the growing season much elongated and curved cells and filaments are to be found. In one instance an unusual number of filaments approaching *M. varians* in form though still of the spinous type were found. It is not improbable that several so-called species of *Melosira* have been included with this variable species in the enumeration.

*Melosira* is the bearer of numerous passive planktonts, the most abundant of which is *Bicosœca lacustris* Clk. Associated with this, and often on the same filament, is the elegant little craspemonad

*Salpingœca brunnea* Stokes. Cells to which several of these flagellates are attached very frequently exhibit a breaking up of the cell contents into eight brownish masses, often of spore-like form, and it is not an uncommon thing to find such parasitized filaments with several empty cells. The eggs of the rotifer *Diurella tigris* are frequently found attached to the filaments of this diatom. The number of cells in the filaments in the silk collections averages 6.4 in 1897, and 7 in 1898, while in the filter-paper collections it averages 3.5 in both years. The numbers per filament range from 1 to 40, and the filaments are wont to be somewhat longer during rapid growth than in periods of decline or minimum.

*Melosira varians* Ag.—Average number, 148,626 (filter-paper 3,455,538). The discussion is based upon silk catches. The species was about equally abundant in 1897 but much less so in previous years. This is a perennial species, reported in every month of the year and in most of the collections. It exhibits two well-defined pulses, a vernal one in April–May and an autumnal one in September–October. The reduction in the minimum intervals varies from season to season and from year to year. It was most pronounced, almost to suppression, in July and August in 1894, 1895, and 1896, and in December–February in 1896–97 and 1898–99. In other seasons the minimum falls to 1,000 to 15,000.

The vernal pulse (146,916) appears in 1895 on April 29, in 1896 (229,235) on May 18, in 1897 (2,419,200) on May 25, and in 1898 (3,164,160) on May 5. The autumnal pulse (150,720) is found in 1895 on October 30; in 1896, on September 16 at 378,900; in 1897 there are two pulses, one on August 30 at 738,000, and the other on November 15 at 458,800; and in 1898 one, on October 18 at 348,000. The autumnal pulses are thus much smaller than the vernal ones and exhibit a greater range in the time of their appearance.

As in the case of many other organisms this diatom also exhibits the phenomenon of recurrent minor pulses at intervals of a few weeks. They range in height from 25,000 to almost 1,000,000, and are largest when found in the proximity of the major pulses. The records are not frequent enough to trace them in all seasons. They appear in January in 1896, 1898, and 1899; in February in 1898; twice in March in 1896; in April in 1896; twice in June in 1897 and again in 1898; in July in 1897 and 1898; in August in 1897 and 1898;

in September in 1898; in November in 1896, 1897, and 1898; and in December in 1894.

The optimum temperatures, omitting the pulse of August 30, 1897, at 80°, all lie below 72°; averaging 65° for the vernal pulse and 62° for the autumnal. But three pulses in all, exceeding 100,000, lie at temperatures above 70°, and but three below 50°. In the case of this species likewise temperatures seem to be potent factors in limiting its seasonal occurrence. The fluctuations in nitrates do not seem to bear any constant relation to its development. The midsummer minimum of the diatom may appear, as in 1896, during an abundance of nitrates (0.5 to 3.0 parts per million—Pt. I., Pl. XLIII.) unusual for the season. On the other hand, a minimum of nitrates (.1 to .35) in August and December, 1898, coincides with a suppression of this species in the plankton. Thus in the presence of food, temperature seems to be a determining factor in the seasonal distribution of this organism. Whipple ('94) expresses the opinion that the growth of diatoms occurs at those seasons of the year when the water is in vertical circulation; that is, when it passes 39.2°. In our waters this generally occurs early in March and late in November. In this species the only pulses which it seems might exhibit the effect of this phenomenon are those of December and March, and neither of them are in any way constant or prominent. Neither of the major pulses, vernal nor autumnal, can be attributed to it. The latter pulse occurs prior to the autumnal overturning of the water.

The vernal pulse usually follows the spring volumetric maximum, and the autumnal one generally appears during a volumetric minimum. No immediate quantitative effect of this species upon the plankton is apparent.

In European waters this is a common planktont, and Apstein ('96) reports vernal maxima in March, April, and May, and an autumnal one of minor value in November.

The number of cells in the filaments varies from one to sixty, and in filter-paper collections averages four, while in the silk catches it varies from seven to fifteen from year to year. The filaments average somewhat longer during the periods of maximum growth, reaching twelve to twenty-five. This species also occasionally bears the flagellates found upon *M. granulata* var. *spinosa*, but not in such abundance. It is quantitatively much less important in our plankton than that species, though this does not seem to be the case in some European waters.

*Meridion circulare* Ag. has appeared but four times in winter planktons, from December to March, and seems to be adventitious.

*Navicula iridis* Ehrbg.*—Average number, 297,307. Appears at irregular intervals, often with flood waters and in the colder months. It seems to be adventitious.

*Navicula* spp.*—Average number, 8,569,038. About twice as abundant in 1897. Under this head I have included a number of species of *Navicula*, and, possibly, even species of genera resembling *Navicula*. The individuals are all of small size, and are principally of the type of the smaller forms of *N. brebissonii* Kütz. and *N. gracilis* Ehrbg. They are quite abundant in collections from Quiver Creek and Spoon River. Their greater abundance in 1898 as compared with 1897 may be caused by the greater movement in river levels in the former year (85.6 ft.) as compared with that of the latter (55.5 ft.). This feature of the distribution of these forms suggests that they are adventitious in the plankton. This view is further supported by the fact that some, though not all, of their apparent pulses appear with flood waters; for example, the pulse of 64,000,000 on May 17, 1898. There are indications, independent of floods, of pulses in April–May and November–December, which may, however, be simply reflections of pulses in the normal habitat of these diatoms—the shores and bottom of the river and its tributaries. They are represented in the plankton at all seasons, and the divergence in numbers is at no time so marked as it is in typical plankton diatoms, such as *Asterionella*.

*Nitzschia amphioxys* (Ehrbg.) Kütz. appeared several times in winter collections, and *N. sigmoidea* (Nitzsch) W. Sm. is adventitious in small numbers in flood waters. Several species of *Pleurosigma* appear at irregular intervals throughout the year in both flood waters and stable conditions and are apparently adventitious, appearing in relatively small numbers.

*Rhizosolenia eriensis* H. L. Smith was noted on a few occasions in winter planktons. Its exceeding transparency and the abundance of silt and debris at the times of its occurrence so obscure it that it may have escaped detection in many instances.

*Stephanodiscus niagaræ* Ehrbg., a common planktont in the waters of the Great Lakes, appeared but once, in May, in our plankton, though the river had for years received, by way of the Chicago River, constant access of water from Lake Michigan. The turbid, sewage-laden, and warmer waters of the Illinois are evidently not favorable for its growth.

*Surirella ovalis* Kütz. var. *minuta* (Bréb.) Kirchner.*—Average number, 761,538. Present sparingly throughout the year, but principally during summer months. Vernal pulse in May.

*Surirella spiralis* Kütz.—Average number, 1,612. Less abundant in the more stable conditions of 1897. This species is most abundant in Quiver Creek and Spoon River. Its fluctuations are slight, irregular, and often appear with flood waters, all of which phenomena indicate its adventitious character in the river plankton.

*Synedra acus* Kütz.*—Average number, 36,558,462 (silk, 308,-330). This species is a perennial planktont, appearing, for example, in 1898 in every collection. It has a highly developed and shifting vernal pulse, and an inconstant and but slightly developed autumnal or hiemal pulse. The vernal pulse appears in 1895 on April 9 at 209,880; in 1896 on April 24 at 366,828; in 1897 on May 25 at 2,620,800 (82,800,000*); and in 1898 on May 10 at 9,043,200 (813,600,000*). The second pulse appears in 1895 on November 14 at 99,360; in 1896 on December 3 at 44,464; in 1897 no pulse occurs; in 1898 it occurs on November 8 at 19,000. As in some other diatoms, there are minor pulses throughout the year, though in this case they are all feebly developed, exceeding 100,000 (silk) in but a single instance. The minor pulses of midwinter often exceed in prominence those of midsummer. The meteoric character of the vernal pulse is very pronounced in this species both in the suddenness of its appearance and its disappearance and in the height which it attains.

The variety *delicatissima* W. Sm. is included here with the type *acus*. During the autumn of 1898 a separate record was kept of the two, with the result that the variety appears to include about four fifths of the individuals at that season. The two are not readily separated. The colorless form recently described by Prowazek ('00) as *S. hyalina* is also included, and it is not uncommon when *S. acus* is abundant. Colorless forms of other diatoms of the plankton, as *Asterionella*, *Melosira*, and *Fragilaria*, also occur, but it would seem from the intergradation with the normal condition that it is a phenomenon of physiological import rather than of specific significance. It would seem desirable that experimental breeding of diatoms should be employed as a test before specific diagnoses utilize this character.

*Synedra capitata* Ehrbg. is occasionally adventitious in the plankton in spring months.

*Synedra ulna* (Nitzsch) Ehrbg.*—Average number, 302,308 (silk, 34,510). This appears somewhat irregularly in the plankton, with a vernal pulse on May 17 of 5,400,000 and an autumnal one November 15 of 1,800,000. It is abundant on the ooze of exposed springy shores after rapid decline of the river, and is probably adventitious in the plankton to some extent from this region.

*Tabellaria fenestrata* Kütz., which is exceedingly abundant in the plankton of European lakes and in our own Great Lakes, was found but a single time in the waters of the Illinois. It can hardly be lack of food elements which prevents its development, and there are times when favorable thermal conditions would seem to be offered in spring and autumn, when the river temperatures do not exceed the summer temperatures of our Great Lakes. It may be that the chemical conditions attending sewage contamination exert a deleterious influence upon this species and others of the genus, such as *T. flocculosa*, which abound in purer lake waters.

### CONJUGATÆ.

This group of algæ is represented in the plankton only by a few desmids, which neither in number, or quantity, play any important part in the ecology of the plankton. The filamentous algæ are abundantly represented in spring in the backwaters of the Illinois River, where they form extensive littoral fringes of "blanket moss," which load down the emerging littoral flora. This fringe is frequently stranded by the retreat of flood waters. In some localities, as in Phelps Lake, it plays a very important part in the food cycle, since by its decay, as temperatures approach the summer maximum, it contributes immediately its store of organic nitrogen to the support of the small algæ and flagellates which develop in great numbers on those waters at that season. Some species of *Spirogyra* and *Zygnema* have a habit of breaking up into short filaments, and in this condition they have often been taken in some quantity in the plankton of the river, but they are so plainly adventitious and irregular that no notice has been taken of them in our enumeration work, and when possible they have been removed before measurement or deducted by estimation from the volumetric records.

The desmids are few both in species and individuals. Seven species have been recognized, of which but four are of general occurrence in the plankton. These are three species of *Closterium* and *Staurastrum gracile.* The latter and *Cosmocladium saxonicum* are the only eulimnetic organisms among them. The center of distribution of the other species is the shore and bottom. The stomachs of fish such as the *Catostomidæ*, the carp, and *Dorosoma cepedianum*, which often feed upon the bottom ooze or slime about aquatic plants, usually contain many desmids, including the species here noted. Other species also are occasionally adventitious in the plankton, and the list might be considerably extended, though the absence of extensive peat bogs in the drainage basin of the river reduces the desmids to a position of much less importance than that which they occupy in more northerly waters.

As a group they exhibit a well-defined seasonal distribution, with a vernal pulse at about the time of the volumetric maximum in April–May and an autumnal pulse of less regular occurrence, location, and size. The optimum temperature for their appearance in the plankton lies below 70°, and in winter months they occur but rarely.

#### DISCUSSION OF SPECIES OF CONJUGATÆ.

*Closterium acerosum* Ehrbg.—Average number, 348. More than three times as abundant in the previous year. This desmid is perennial in the plankton, having been found in every month of the year, but at irregular intervals, and never in large numbers. Its distribution is such as to suggest that it is at the most only semilimnetic in habit. The numbers are too small to follow closely the seasonal distribution. There are pulses on May 3 (3,200), September 6 (2,400), and November 1 (2,500) in 1898; and in 1897 a pulse on June 28 (2,000) and one on September 21 (24,000). In previous years vernal pulses in April and occasional autumnal pulses are to be noted. In so far as the optimum temperature is indicated, it seems not to lie near either extreme, and above rather than below the average for the year.

*Closterium gracile* Bréb.*—Average number, 49,616 (silk, 305). This species was found in small numbers from March to December, and shows pulses on May 17 (1,600) and September 27 (6,400) at temperatures of 64° and 73°. The tenuity of the form of the frustule of this species suggests a limnetic habit.

*Closterium lunula* Ehrbg.—Average number, 556. This also is a perennial species, and is somewhat more abundant and constant than *C. acerosum*. It likewise has a vernal pulse, which in 1895 appears on April 29 (2,915); in 1896, on May 1 (5,364); in 1897, on May 25 (3,200); and in 1898, on May 24 (6,000). In both this species and *C. acerosum* there are slight indications of recurrent minor pulses which are often coincident in the two species. Nine such movements appear in 1898. The autumnal pulses are less regular in their appearance and size than the vernal, and appear from September to November. The optimum temperatures seem to lie between 45° and 70°. This species is only semi-limnetic, and never attains the fluctuations which characterize most limnetic organisms. Doubtless other so-called species of *Closterium* have been included among the variable organisms referred here to *C. lunula* and *C. acerosum*.

*Cosmarium constrictum* Delp. was found occasionally from March to September, and is probably adventitious.

*Cosmocladium saxonicum* De By.—A single isolated pulse of this minute limnetic desmid appeared in the filter collections of September, 1897. It was first noted on August 31 and disappeared after September 29, and was never found at other times in the plankton. The pulse culminated September 9 at 13,500,000*.

*Gonatozygon brebissonii* De By.—The filaments of this desmid were noted in the plankton only in March, 1899, attaining a maximum of 136,800 on the 14th.

*Staurastrum gracile* Ralfs.—Average number, 31. About two hundred times as abundant in the plankton of 1897. It occurs from March to January. No vernal pulse was detected, but an autumnal one of 14,000 appears September 29. It appears in much larger numbers in the filter-paper collections, and is probably a limnetic planktont in our waters.

Undetermined species of *Penium*, *Arthrodesmus*, and *Docidium* have been found in the plankton but always singly. They are doubtless adventitious.

## PHANEROGAMIA.

The *Lemnaceæ* are represented in our waters by several species of *Lemna*, by *Spirodela*, and by two species of *Wolffia—brasiliensis* and *columbiana*. The first two genera are predominantly floating surface-plants, while the last occurs at all levels, is taken with the plankton, and has been treated in our measurements and enumerations as a limnetic organism.

*Wolffia brasiliensis* Weddell.—Average number, 2; in 1897, 13. It appears irregularly in river planktons from the last of March till January, and is somewhat more abundant in late summer and autumn. The seining operations of fishermen in the river and tributary backwaters have much to do with its appearance in the plankton of the river.

*Wolffia columbiana* Karsten.—Average number, 7; in 1897, 41. With the preceding species. Neither of these species are sufficiently abundant greatly to affect the ecology or quantity of the plankton of the river, though they are of more importance in the backwaters. Owing to their size and duration they compete with the smaller organisms of the phytoplankton, but do not serve as food for any of the zoöplankton.

## PROTOZOA.

Average number, 111,731,000. The number of species exceeds 147 (+38), distributed as follows: *Mastigophora*, 60(+10); *Rhizopoda*, 31 (+28); *Heliozoa*, 5; *Sporozoa* (3); *Ciliata*, 45; and *Suctoria*, 5,—the numbers in parentheses indicating the additional forms whose specific rank was not recognized in the enumerations.

The *Protozoa* occur in great numbers (Table I.) in every collection of the year. Owing to the fact that the totals are a conglomerate of two methods of collecting, of a large number of species of many divergent seasonal tendencies, and of both eulimnetic and adventitious forms, their seasonal fluctuations have no particular significance which is not better treated either in connection with the subdivisions of the class or with the individual species. In the totals, traces appear of the vernal pulse, of the midsummer maximum of the chlorophyll-bearing *Mastigophora*, and of the autumnal-winter wave of *Ciliata*.

The *Protozoa*, through the *Mastigophora*, share with the algæ the synthetic function in the elaboration of food from inorganic or partially disorganized organic contents of the water. They utilize decaying organic matter as food, and are thus primary links in the cycle of food relations. Some of them feed upon bacteria, upon algæ, or even upon other animals, and thus become secondary or tertiary links in the chain.

### MASTIGOPHORA.

(Plates I. and II.)

Average number, including, without duplication, both silk and filter-paper collections, 95,856,449. In the collections of 1897 they were five times as abundant as a result, in part at least, of the extended low-water period, sewage contamination, and extension of high temperatures during the late autumn of that year (Pt. I., Pl. XI.).

The *Mastigophora* abound in every collection and occur at all seasons of the year. Four fifths of them occur, however, between the first of April and the last of September. They are predominantly chlorophyll-bearing organisms, and have their greatest numbers during the same season in which the land flora attains its growth. They spring into abundance with the opening buds of April, and vanish from the plankton when frost cuts off the foliage in autumn. There are, it is true, some species, such as *Synura*, which grow luxuriantly at winter temperatures, but these are generally of the chrysomonad type, with yellowish or brownish chromoplasts. The bright green chlorophyll-bearing flagellates are in the main *summer* planktonts. Since water temperatures do not fall below 32°, the phytoplankton is exempt from this risk of destruction against which the land flora must provide. We find, accordingly, that the most of the *Mastigophora* are wont to occur in diminished numbers and irregularly in the plankton throughout the winter. This appears in the records of the more common species, and fuller examination would doubtless greatly increase the number which thus winter over in reduced numbers.

I have already called attention to the fact that there are in 1898–99 recurrent pulses in the *Chlorophyceæ* and *Bacillariaceæ* at

Location and Amplitude of Pulses of Chlorophyll-bearing Organisms in the Illinois River.
Number of Millions of Individuals per M.³

| | Date | Amplitude | Date | Amplitude | Date | Amplitude | Date | Amplitude | Date | Amplitude | Date | Amplitude |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1897 | | 1897 | | 1897 | | 1897 | | 1897 | | 1897 | |
| Chlorophyceæ | July 14 | 538 | Aug 10 | 135 | Sept. 7 | 169 | Sept. 29 | 496 | Oct. 19 | 390 | Nov. 23 | 473 |
| Bacillariaceæ | " " | 11,459 | " 17 | 424 | Missing | —— | " " | 407 | " 26 | 107 | Missing | —— |
| Mastigophora | " " | 367 | " 10 | 236 | Sept. 7 | 3,247 | " " | 1,741 | " 19 | 548 | Nov. 23 | 90 |
| Interval, in days, | | 27 | | 28 | | 22 | | 20 | | 35 | | |

| | Date | Amplitude | Date | Amplitude | Date | Amplitude | Date | Amplitude | Date | Amplitude | Date | Amplitude |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1897 | | 1898 | | 1898 | | 1898 | | 1898 | | 1898 | |
| Chlorophyceæ | Dec. 21 | 5 | Jan. 25 | 108 | Missing | —— | Mar. 22 | 25 | May 3 | 212 | June 14 | 47 |
| Bacillariaceæ | " " | 17 | " 21* | 49 | Feb. 15 | 29 | " " | 43 | Apr. 26<br>May 10 | 3,453<br>3,865 | " " | 1,040 |
| Mastigophora | " " | 60 | " 25 | 43 | " 22 | 43 | " " | 43 | May 3<br>" 17 | 1,064<br>231 | " 21 | 218 |
| Interval, | 28 | 35 | | 28 | | 28 | | 42 | | 42 | | |

* January 11 has a pulse of 122.

LOCATION AND AMPLITUDE OF PULSES OF CHLOROPHYLL-BEARING ORGANSIMS IN THE ILLINOIS RIVER.
NUMBER OF MILLIONS OF INDIVIDUALS PER $M.^3$—*Concluded*

| | Date | Amplitude | Date | Amplitude | Date | Amplitude | Date | Amplitude | Date | Amplitude |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1898 | | 1898 | | 1898 | | 1898 | | 1898 | |
| Chlorophyceæ | July 19 | 277 | Aug. 9 | 371 | Aug. 30 | 189 | Sept. 27 | 71 | Oct. 25 | 29 |
| Bacillariaceæ | " " | 789 | " " | 444 | " " | 210 | " " | 215 | " " | 131 |
| Mastigophora | " " | 295 | " " | 497 | Missing | —— | " 20 | 63 | Missing | —— |
| Interval, in days, | 35 | | 21 | | 21 | | 28 | | 28 | |

| | Date | Amplitude | Date | Amplitude | Date | Amplitude | Date | Amplitude | Date | Amplitude |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1898 | | 1898 | | 1899 | | 1899 | | 1899 | |
| Chlorophyceæ | Nov. 15 | 34 | Dec. 15 | 66 | Jan. 10 | 22 | Feb. 21 | 100 | Mar. 14 | 43 |
| Bacillariaceæ | " 22 | 295 | " " | 437 | " " | 64 | " 14 | 90 | " " | 49 |
| Mastigophora | " 15<br>" 29 | 36<br>74 | " " | 148 | " " | 23 | " 21 | 743 | " " | 15 |
| Interval, | 28 | | 23 | | 26 | | 42 | | 21 | |

intervals of several weeks, and that such pulses can also be traced back into 1897 as far as the collections were made at weekly intervals—that is to the early part of July. A similar periodicity on the part of the *Mastigophora*—the greater part of which are also chlorophyll-bearing—is even more evident. Not only is this periodicity present in this group, but it coincides approximately in the location of its maxima and in their relative development with that found in the *Chlorophyceæ* and *Bacillariaceæ*. The following table, which gives the dates of culmination of the pulses of these three groups from July 1, 1897, to April 1, 1899, will serve to demonstrate this point more clearly, and a graphic presentation of the data will be found in Plates I. and II.

There are twenty-two of these recurrent pulses in the period from July, 1897, to March, 1899. Of the sixty-six possible maxima only five are missing, or at least not apparent in our data, and but ten culminate on other dates than the one (of collection) most to be expected. These ten in *every* case culminate either a week prior or subsequent to that in which the other two groups reach their maxima. These divergences may be due to the error incident to the interval of collection, and their approximation in time is still corroborative of the tendency towards recurrent periods of growth. These exceptions are no greater than might be expected to occur in the unstable fluviatile environment and within the large margin of error of the plankton method.

There are twenty-one intervals between July 14, 1897, and March 14, 1899, with a range in length of 20 to 42 days and an average of 28.95. The intervals in days with the numbers of instances of each are as follows: 20 (1), 21 (3), 22 (1), 23 (1), 26 (1), 27 (1), 28 (7), 35 (3), and 42 (3), days. The effect of the weekly interval of collection is seen in the preponderances at 21, 28, 35, and perhaps at 42, days. There is evidently a tendency towards the interval of 28 days. Nine of the 21 pulses are grouped about this interval; 6, about that of 21; while 3 are at 35 and 3 at 42. If there be such a tendency it is but natural that with a weekly interval of collection there should also appear minor preponderances at 21 and 35 days. Traces of a similar rhythm may be found in the period of weekly collections in 1896 (Pt. I., Table III.).

In some instances the environmental conditions at these times of departure are such as to suggest that they may have produced the shifting in the position of the maxima. Thus the pulse of January 25, 1898, appears after a 35-day interval, but in the midst of the rising winter flood, to whose effect the delay may be attributed. In both 1896 and 1898 the 28-day rhythm is interrupted at the time of the vernal pulse in April–May. It appears as though these recurrent pulses—if such exist—were submerged in the greater vernal increase. The double summit of the vernal pulse in the curve of the *Bacillariaceæ* and *Mastigophora* (Pl. II.) for 1898 suggests the compound character of this pulse in the case of these groups of organisms at least. The time interval in the case of the vernal interruption is also significant. In 1898 there are two pulses between March 22 and July 19, at intervals of 42 days—a total of 84 days, which is the equivalent in duration of three 28-day intervals.

The total number of species of *Mastigophora* recorded by me from the plankton of the Illinois River is over sixty. This number will be increased to more than seventy if forms not separated in our enumerations be distinguished as separate species.

The *Protomastigina* (including the *Bicosœcidæ* and the *Craspedomonadidæ*) are well represented in the plankton by passive limnetic species which are principally sessile on other planktonts. These are *Bicosœca lacustris*, *Salpingœca brunnea*, *S. minuta*, and *Diplosiga frequentissima*. *Asterosiga radiata* is a eulimnetic representative and *Anthophysa vegetans* an adventitious one. As a group they are more abundant during the warmer part of the year.

The *Chrysomonadidæ* are also well represented, and include the most abundant flagellates of the plankton of the colder months. *Synura uvella* is quantitatively the largest factor furnished by this group. It is supplemented by *Syncrypta volvox*, and the various forms of *Dinobryon*, *Uroglena*, and *Mallomonas*. The last two genera have more of a summer range of occurrence, but are not of quantitative importance in the waters of the Illinois.

The *Cryptomonadidæ* are represented only by *Chilomonas* and *Cryptomonas*, and are of somewhat constant, though of minor, importance quantitatively.

The *Euglenidæ*, on the other hand, are, in our waters at least, second to no coördinate group in their quantitative importance. They are individually of relatively large size, and they occur in great numbers throughout the summer months, replacing the *Chrysomonadidæ* of the colder seasons of the year. *Euglena* *viridis* is the most abundant, and it is associated with other species of the genus, with species of *Amblyophis*, *Phacus*, *Lepocinclis*, *Chloropeltis*, *Colacium*, and *Trachelomonas*, especially the latter.

The *Peridiniidæ* are quantitatively of considerable importance in the plankton of our Great Lakes (Kofoid, '95), but in the Illinois River they are of little significance, at least the larger forms such as *Ceratium*. Smaller species such as *Peridinium tabulatum* and *Glenodinium cinctum* are more abundant. As a group they do not show any marked seasonal preferences.

The *Volvocidæ*, on the other hand, are of more than the usual consequence in the plankton of the Illinois. The group is represented by the curious *Chloraster gyrans*, by the sporadic and meteoric *Carteria multifilis*, and by the colonial genera *Eudorina*, *Pandorina*, *Pleodorina*, *Platydorina*, and *Volvox*. As a group they are almost exclusively summer planktonts.

The *Mastigophora* as a whole are, next to the *Bacillariaceæ*, the most abundant of the synthetic organisms of the plankton. Their quantitative importance has not hitherto been sufficiently demonstrated in the plankton of fresh water, owing it may be to their escape through the silk net in the ordinary methods of collection. It seems quite probable also that they may be present in our warm and fertile waters in much greater abundance than they are in the colder and clearer waters of most lakes. This is especially true of the *Euglenidæ* and *Volvocidæ*, perhaps less so of the *Chrysomonadidæ* and *Peridiniidæ*.

### DISCUSSION OF SPECIES OF MASTIGOPHORA.

*Amblyophis viridis* Ehrbg.*—Average number, 63,014 in 1897. It occurred throughout the summer in 1897, from May to October, with a maximum of 1,440,000 on August 31. Apparently a summer planktont but never very abundant.

*Anthophysa vegetans* (O. F. Müll.) Bütschli.—This was identified in the plankton of June, 1898. It is very abundant at times on various substrata in stagnating water, and from such places becomes adventitious in detached fragments of colonies in the plankton.

*Asterosiga radiata* Zach.—This interesting colonial and limnetic choanoflagellate, described originally from the plankton of German lakes, has been found but a single time in our plankton—in the latter part of August, 1896. It is one of many illustrations of the cosmopolitan distribution of plankton organisms.

*Bicosœca lacustris* J. Clark*.—Average number, 112,896. Only one third as abundant in 1896, and four times as many in 1897. This minute flagellate is found in our waters sessile upon the filaments of *Melosira*, principally *M. granulata* var. *spinosa*. It occurs more frequently upon the dead frustules than upon live ones, and upon those of the shorter form than upon the longer. It has appeared also upon *Dinobryon sertularia*, *Pediastrum pertusum*, and *Richteriella botryoides*. It exhibits a considerable range of variation in proportions, in the amount of lateral compression, and in the length of the pedicels. These variable forms are, however, connected with the type as described by Clark, and are not, in my opinion, to be designated as distinct species. Zacharias ('94) has described one of these variants as *B. oculata*. I regard it as a growth condition of *B. lacustris*, and not as specifically distinct from it.

Its seasonal distribution in 1898 is somewhat peculiar. It appears as two quite symmetrical pulses, the first extending from early in June till the middle of July, and culminating on June 14 at 3,801,600. The approach of this pulse is abrupt and its decline somewhat gradual. The species does not reappear until September 13. The autumnal pulse culminates October 11 at 486,000, then gradually declines, and disappears November 1. There is no record of its occurrence in 1898 outside of these two pulses. In 1897 it is found irregularly from May to August, and in 1896 in February and from May to December, with pulses in May, June, July (2), August, and October.

In 1898 its optimum temperatures appear at 82° and 65°, and its pulses in other years do not occur below 57°. It thus belongs to the plankton of the warmer months.

Its seasonal distribution falls within that of the limits of its host *Melosira*, and in 1896 and 1898 their vernal pulses coincide, and the same correlation appears in all but one of the pulses of 1896. Not all *Melosira* pulses, however, are attended by an increase in *Bicosœca*. Thus in the late summer and fall of 1897 *Melosira* fluctuated without any appearance of *Bicosœca*. In the autumn of 1898 the pulse of *Bicosœca* on October 11 appears on the decline of the September pulse of *Melosira*, in which the host made no corresponding increase. *Melosira* is thus apparently essential for any marked increase of *Bicosœca* in the plankton, but is not in itself the primary cause for its appearance in the plankton.

*Carteria multifilis* (Fres.) Dill.*—Average number, 2,365,384. In 1897 more than one hundred-fold as abundant. This species was recognized only in the autumnal and hiemal planktons, from August till January in 1897–98 and from October to February in 1898–99. It is not easily and with certainty identified by the usual methods of plankton counting, and probably other species of similar habitus may have been included to some extent; and, on the other hand, many *Carteria* may have been thrown with the "unidentified" flagellates, especially in earlier years. This species occurs throughout the whole range of temperatures, and its maximum development (6,476,400,000) was attained October 5, 1897, at 70°. A pulse prior to this appeared September 7, at 2,846,250,000. From the major pulse in October there is a gradual decline as the minimum temperatures are reached.

The remarkable outbreak of *Carteria* in the autumn of 1897 was associated with unusually low water (Pt. I., Pl. XI.) and concentration of sewage and decrease in current. The water of the stream was of a livid greenish-yellow tinge, due principally to great numbers of *Carteria*, which developed to the exclusion or diminution of other chlorophyll-bearing flagellates such as *Euglena*, and of diatoms such as *Melosira*. This unusual development seems to have been a disturbing factor in the usual seasonal routine of the autumnal plankton of that year.

The distribution of *Carteria* in the river was remarkable. It formed great bands or streaks visible near the surface, or masses which in form simulated cloud effects. The distribution was plainly uneven, giving a banded or mottled appearance to the stream. The bands, 10 to 50 meters in width, ran with the channel or current, and their position and form were plainly influenced by these factors. No cause was apparent for the mottled regions. This phenomenon stands in somewhat sharp contrast to the distribution of the usual water-bloom upon the river, which is generally composed largely of *Euglena*. This presents a much more uniform distribution, and unlike the *Carteria* is plainly visible only when it is accumulated as a superficial scum or film. *Carteria* was present in such quantity that its distribution was evident at lower levels so far as the turbidity would permit it to be seen. It afforded a striking instance of marked inequalities in distribution within small areas, of at least one plankton organism.

*Carteria* showed great variation in the amount of chlorophyll present. Some individuals were practically colorless. It seems very probable that in the presence of great abundance of partially decayed organic matter such as occurs in a sewage-laden stream, *Carteria* may become largely holozoic in its nutrition, as Zumstein ('99) has shown to be the case with *Euglena*. The literature of fresh-water plankton contains no record of a similar preponderance of *Carteria* in other localities, though its occurrence has been occasionally noted in the plankton.

The chemical conditions under which this great pulse of *Carteria* appeared in the autumn of 1897 can be followed in Part I., Plate XLIV and Table X. The high chlorine and the great increase in free ammonia and nitrites indicate the decay of sewage; the high nitrates and albuminoid ammonia show that there was no lack of some at least of the important sources of food. The two principal pulses appear September 7 (2,846,250,000) and October 5 (6,476,-400,000), with a minimum of 680,400,000, on September 21, separating them. Both of these pulses are attended by sharp declines in nitrates and nitrites and free ammonia, and very slight decreases in organic nitrogen and albuminoid ammonia. Either the first three substances named or those matters which supply them by their decay, are thus noticeably utilized at the times of these pulses.

The relation of the *Carteria* to the volumetric pulses is (Pt. I., Pl. XI.) not a constant one. The *Carteria* pulse of September 7 lies in a slight depression between two maxima of the volumetric curve, and a week prior to the autumnal culmination on September 14 at 19.8 cm.$^3$ per m.$^3$. It thus appears during the growth period of this volumetric maximum. The second and larger pulse of *Carteria*, on October 5, *coincides* with the second volumetric maximum, and in fact fluctuates throughout with it. Though *Carteria* constitutes but a small part of the actual catch of the silk net, owing to leakage through the silk, it is apparently an important factor in the food cycle which builds up such maxima.

*Ceratium brevicorne* Hempel.—This species appeared in small numbers in isolated instances from April through October. It varies towards *C. hirundinella*, but the small numbers in which it has occurred have not as yet afforded sufficient ground for regarding it as a variety of that species. It occurs most frequently in August and September, and is apparently a warm-water planktont.

*Ceratium cornutum* Ehrbg. was found but once—in June, 1896.

*Ceratium hirundinella* O. F. Müll. was not noted in our plankton in 1898, but in 1896 was found from June to October, with a pulse of 19,200 on June 6. It was recorded only at temperatures above 57°, and is apparently a warm-water planktont. It has but an insignificant part in the potamoplankton of the Illinois River and its backwaters, though quite abundant in the summer plankton of Lake Michigan (Kofoid, '95). It seems not to have survived the transit through the sewage-laden waters of Chicago River or to thrive in the conditions prevailing in the Illinois River, though common generally in fresh-water plankton of the temperate zone.

*Chilomonas paramæcium* Ehrbg.*—Average number, 555,000. This flagellate, which is frequently abundant in aquaria or stagnant water, appears also in the plankton of the Illinois River. There is in 1898 a vernal pulse, culminating at 10,800,000 on April 26, and there are scattered records from October to February.

*Chloraster gyrans* Ehrbg.—This rare and unique flagellate was found in but two collections—in July and August, 1898—and only in small numbers.

*Chloropeltis monilata* Stokes.*—Average number, 362,941 in 1897. This is a summer planktont, appearing at irregular intervals from the last of May until the middle of September. It was not found in 1898. A maximum of 10,800,000 appears on August 31.

*Colacium calvum* Stein.—The attached stage only of this flagellate was observed, and was recorded only in 1896 and 1897. It appears from the middle of April to the first of October, and is usually found upon *Polyarthra platyptera*. It has occurred occasionally upon several species of *Brachionus* and upon *Chydorus sphæricus*. The largest number recorded (162,792) appeared on April 17, 1896, upon *Polyarthra*, usually upon the body and more rarely upon the oar-like appendages. It is often exceedingly abundant upon the planktonts of backwater ponds.

*Colacium vesiculosum* Ehrbg.—This species is much less abundant than the preceding species in our waters, and was found only in June and September, upon *Cyclops albidus* and *Polyarthra*.

*Cryptomonas ovata* Ehrbg.*—Average number, 121,154. This species has been recorded principally in the autumnal or hiemal plankton. It escapes through the silk net readily, and was rarely found in collections of earlier years. In 1895 it occurred from July till the last of October, and in 1898 was common in the December plankton.

*Dinobryon sertularia* Ehrbg.—Like most typical planktonts, *Dinobryon* is an exceedingly variable organism, and the variation finds its expression in the form and proportions of the loricæ and in their arrangement and continuity in colonies. Divergences from described and figured species are thus at once apparent, and they have been utilized by systematists, notably by Lemmermann ('00) and by Brunnthaler ('01) as the basis for the establishment of a large number of new species. The validity of these species, in my opinion, must rest ultimately upon careful experimental evidence of their present mutual genetic independence under normal conditions of growth. From my own observations upon large numbers of colonies and individuals distributed throughout the range of their seasonal recurrence in six years in our waters, I am inclined to regard all as belonging to a single species, and the different types as mere growth varieties. The rapidity of growth and the age of the individual or of the colony are, I believe, important factors in the determination of the form of the lorica, and its various forms are therefore not of specific value, but rather of physiological significance. It is a simple matter to find individuals, or even colonies, conforming to the descriptions of the several species, but it is not so easy to refer all individuals and all colonies to the described types. They intergrade—nay, more, two, or even more, "species" are not infrequently *combined in the same colony.* I have never found all the forms in a single colony, but such combinations as *angulatum-divergens*, *divergens-angulatum-stipitatum*, *sertularia-angulatum*, and *sertularia-undulatum* have been observed by me. These combinations are most frequent in large colonies, and, indeed, the number of "species" in a colony is apparently a function of its size. The slender growing tips are wont to assume the *stipitatum* type of lorica and colony, and the older loricæ at the base to conform to that of *sertularia*, *divergens*, or *angulatum*. Small colonies as a rule belong to a single "species." These combinations are generally most evident during the maximum period of growth; that is, when *Dinobryon* is multiplying rapidly, though they may appear at any season of its occurrence.

In the enumeration of *Dinobryon* five types were recognized, and the individuals were assorted to these "species," viz.: *D. sertularia, stipitatum, divergens, angulatum,* and *undulatum.* Some corroboration of the view that we are dealing with a single variable organism and not with five distinct species may be seen in the coincidence of the seasonal distribution, and of the rise, culmination, and decline of the pulses of the five different forms.

Since these varieties have such a similar seasonal distribution I shall treat them as a whole, discussing subsequently any individual peculiarities which are noteworthy. The average number of individuals of *Dinobryon sertularia,* including all its varieties, in 1898 was 1,979,785. In 1897 the average was much smaller (79,352) owing to the few collections in the winter, when it is most abundant, and to its suppression in the prolonged low water of the autumn of that year. The relative frequency of these different varieties—for I shall treat them as such—is shown by the average per cubic meter for the year in 1898, viz.: *D. sertularia,* 407,602; *D. sertularia* var. *stipitatum,* 603,911; *D. sertularia* var. *divergens,* 866,083; *D. sertularia* var. *angulatum,* 101,358; *D. sertularia* var. *undulatum,* 831. These figures are only approximate, since colonies containing more than one variety have all been included with the predominant variety in the colony, which is usually *sertularia* or *divergens,* consequently *angulatum* and *undulatum* are more numerous than indicated by these figures.

The seasonal distribution of *Dinobryon* in our waters is well defined, and is sharply limited to the period from November to June. Its earliest recorded appearance was November 8 in 1898, while in 1896 and 1897 it was not found until in December. It lingers well into June in 1896 and 1898—the two years in which the spring collections were of sufficient frequency to trace its decline. In 1898 the latest record was on June 28. Most of the records after May are irregular and sporadic. It is thus absent from the plankton of the Illinois River from the last of June till November or December. In 1895–1896 there was also a winter interval in which no *Dinobryon* was recorded during the December–January flood (Pt. I., Pl. IX. and X.). In 1897–1898 a similar interval appears, and continues almost to the end of the slow rise of the flood which culminated in March. Rising floods thus do not favor the development of *Dinobryon* in channel waters of the Illinois.

The interval of collection in 1894–95 is too great to trace the seasonal fluctuations of *Dinobryon*, though there are indications of a maximum pulse on April 29. In 1895–96 there is a slight development in November prior to the rise of December, in which *Dinobryon* again disappears. A slight pulse of 3,192 appears on the declining flood (Pt. I., Pl. X.) on January 25, and declines again with the rise in February to reappear on February 20 at 42,588. Another decline in *Dinobryon* attends the rise in river levels in February–March, and after a fortnight of falling levels a third pulse of 2,531,280 is seen on March 17. Two other pulses attend the decline of this flood, one upon April 29 (800,064) and the other on May 18 (339,624). On the decline of the June rise of this year a late and unusually large pulse for the season appears (June 11) at 2,438,400. An examination of the hydrograph will indicate that almost without exception these pulses attend the run-off of impounded backwaters after recent invasion, or, as on April 29 and May 18, after a temporary check in the run-off. During those times when the channel contributes to the backwaters, that is, during rising floods, *Dinobryon* declines in numbers; and, on the other hand, it reaches its greatest development in channel waters during the run-off of the flood.

In 1896–1897 the interval of collection (Pt. I., Table III.) is again too great to trace satisfactorily the fluctuations of *Dinobryon*. There is a pulse on December 3 of 157,609 and on April 27 of 172,800.

In 1897–98 *Dinobryon* appears first on December 7, with a pulse of 1,807,200, during a period of low water and ice blockade with no backwater contributions. It declines, and after December 21 does not again return until March 22, when an isolated record appears. The vernal pulse begins April 19 and culminates May 10 at 84,841,600 on the declining spring flood (Pt. I., Pl. XII.). *Dinobryon* declines at once during a fortnight of rising water, and two minor pulses on the decline of the flood—one on June 7 of 70,400 and one on June 28 of 219,840—complete its vernal cycle.

The hydrographic conditions in 1898–99 were very different from those of the preceding season, and we find a marked change in the seasonal occurrence of *Dinobryon*. From November to March there are three rises to overflow stages (Pt. I., Pl. XII. and XIII.) with intervening declines of a month's duration. There is a pulse of *Dinobryon* in each of these periods of declining flood. The pulse of 275,200 on December 20 follows the November flood, and it is followed by a minimum of 1,500 on the rising flood of January 10. The numbers slowly increase until a meteoric rise on February 7 to 6,486,700 and on February 14 to 22,621,440 is followed again by another decline, to 25,920 on February 28, with the sudden flood of that week. During the maximum flood stage in March (Pt. I., Pl. XIII.) no *Dinobryon* was recorded, but it reappeared again on March 21. The suspension of our plankton operations interrupted the further tracing of the fluctuations.

From the facts above detailed it is very evident that the pulses of *Dinobryon* occur in channel waters at times when the run-off of impounded backwaters is making its greatest contribution to the river plankton. These are times of greatest stability of the environment in all respects save river level and its sequences. The impounded waters have come from regions of slight current and decaying vegetation, and there has been time in those localities for the decay of sewage and debris, and for the growth of planktonts such as *Dinobryon*. These conditions of the environment are therefore favorable for the growth pulses of *Dinobryon*. The phenomenon of pulses of growth is not, however, to be considered as merely the result of declining floods. These afford a favorable environment and doubtless determine within certain limits the time and the extent of the pulse. The phenomenon is one common to most plankton organisms, and occurs in *Dinobryon* of lakes where floods are of little significance.

Any evidence of recurrent minor pulses in *Dinobryon* at brief intervals is lacking.

*Dinobryon* has been found in our plankton through practically the whole range of temperatures, but it disappears when maximum summer heat is reached and does not return until the water cools to 45° or lower. Large pulses, such as that of February 21, 1899 (22,621,440), have developed at temperatures approximating 32°, and largely under the ice. The vernal pulse of April–May has been recorded at temperatures ranging from 60° to 79°, but generally nearer the former. No well-defined optimum temperature appears, and the seasonal distribution suggests that the high temperatures of our summer waters are inimical to *Dinobryon*. That its absence from the plankton at that time is not due merely to low-water conditions is shown by the December pulse in 1897, under the most pronounced type of such conditions.

*Dinobryon* is a common planktont in the Great Lakes (Kofoid, '95) during the summer months, but surface temperatures here rarely exceed 68°, and are 10° to 20° below those of the Illinois River. In German lakes Apstein ('96) finds the maximum development of *Dinobryon* in June and a continuance through the summer in reduced numbers, but temperatures are also 10° to 20° (F.) lower than in our waters. In the case of *D. stipitatum* there is a second maximum in August. Lauterborn ('93) finds *Dinobryon* throughout the winter in the plankton of the Rhine, with a maximum in April–May, with diminished numbers during the summer, and a second maximum in September.

The filter-paper collections give very much larger numbers, owing partly to the inclusion of small colonies which escape through the meshes of the silk net in the usual method of collection. The numbers are increased at least thirty-fold if filter collections are utilized instead of silk, as above.

The size of the colonies in the collections varies greatly, the averages ranging from three to forty-eight cells. The maximum pulse is attended or followed by a considerable decrease in the size of the colony. In the pulse of February 21, 1899, the average number of cells in the colony falls from thirteen to sixteen, during the rise of the pulse, to seven, at its culmination. On the pulse of May 10, 1898, the average is thirteen, and a week later, when the pulse declines from 16,153,600 to 43,200, the average size of the colony drops to three cells. Cysts also are most frequent during and subsequent to maximum development. *Dinobryon* is sometimes covered with large numbers of minute choanoflagellates, probably *Salpingœca minuta* Kent. Frequently colonies occur in which only the younger cells are alive.

*Dinobryon* is, in the light of its distribution, one of the important synthetic planktonts of the colder months, and is one of the primal links in the chain of food relations of that season, serving as food for some of the winter *Cladocera* and *Copepoda*. The fact that its maxima frequently occur when volumetric minima appear—as, for example, on February 21, 1899—indicates that *Dinobryon* does not directly contribute much, even at its maximum development, to the volume of the plankton taken in the silk net. On the other hand, its rapid multiplication, as evidenced by its meteoric pulses, may serve to build up a more permanent and bulkier animal plankton, and thus indirectly, in a cumulative way, it may be of considerable quantitative importance.

The inclusion of all the variants of *Dinobryon* as a single species has been favored by Wesenberg-Lund ('00), who regards *D. stipitatum* as the summer form of *D. sertularia.* In our plankton, *D. stipitatum* has occurred sporadically in December and March, but it is most abundant during the vernal pulse in April–May. Its distribution thus in the main supports that author's contention in that it is found during the warmer portion of the seasonal cycle of *Dinobryon* in our waters, though not in our summer plankton. It is not desirable in this connection to enter further into a discussion of problems which have been raised by the splitting up of *Dinobryon* into so large a number of forms. Lemmermann has found seventeen species and varieties within the limits of the subgenus *Eudinobryon.* A discussion of their validity involves not only some perplexing problems of synonymy, but also an extensive examination of a large amount of material showing seasonal changes, and, above all, a series of experiments which shall demonstrate the limits of variation within a known line of descent and in the seasonal range of environmental conditions. It involves, moreover, the fundamental question of the criterion of species. The papers of Lemmermann ('00) and Brunnthaler ('01) have appeared since my work of enumeration was completed. I recognize among the forms which they have sought to establish the following which occur in our plankton: *D. sertularia* Ehrbg., *D. sertularia* var. *thyrsoideum* (Chodat) Lemm., *D. sertularia* var. *alpinum* Imhof, *D. protuberans* Lemm., *D. sociale* Ehrbg., *D. stipitatum* Stein, *D. stipitatum* var. *americanum* Brunn., *D. stipitatum* var. *bavaricum* (Imhof) Zach., *D. elongatum* Imhof, *D. elongatum* var. *undulatum* Lemm., *D. cylindricum* Imhof, *D. cylindricum* var. *palustre* Lemm., *D. cylindricum* var. *schauinslandii* (Lemm.) Lemm., *D. cylindricum* var. *pediforme* (Lemm.) Lemm., *D. cylindricum* var. *divergens* (Imhof) Lemm., and *D. cylindricum* var. *angulatum* (Seligo) Lemm.

As a result of my attempts to refer *all of the individuals* which I have seen in my work of enumeration to *species*, I am of the opinion that we are dealing in the case of the species of *Dinobryon* above cited with a single variable organism, whose *extremes* of variation only have been regarded as separate species. The connecting links are sufficiently abundant still and the union of several types in a single colony is sufficiently frequent to lend some weight to my conclusions with regard to those forms which have been under my observation. In the interests of utility as well as in the interests of well-grounded taxonomy, it is extremely desirable that the establishment of new species among variable plankton organisms should be attempted with extreme caution and only after the fullest study of the range and conditions of variability. The instability of the taxonomic structures which Brunnthaler and Lemmermann have recently raised, is evidenced by the differences in synonymic, varietal, and specific rank given to the variants of *Dinobryon* by these two systematists, who have but recently monographed the group, largely if not wholly from the systematic point of view. The changing estimate of validity which Lemmermann himself has put upon his own species or varieties—for example, *schauinslandii*, *pediforme*, and *curvatum*—gives further evidence that the basis upon which they rest is at the best but slight. It is my firm conviction that the establishment of new species among the organisms of the plankton of fresh water can be satisfactorily accomplished only after careful analysis of the limits of variation within the range of environmental conditions. Standards less comprehensive than this can yield results of but temporary or local value and can lead to but little permanent advance in science, and they bring only perplexity and chaos where order should reign.

*Diplosiga frequentissima* Zach.*—Average number, 1,736,538. This minute flagellate is found upon the rays of the colonial diatom *Asterionella*, often in great numbers and so thickly set as to leave little unoccupied space. It was found in each year at the time of the vernal pulse of *Asterionella* in April–May, and was as a rule most abundant immediately after the maximum growth of *Asterionella* had been attained. Beyond an isolated occurrence in January it was not recorded at other times than during the months of April and May.

*Eudorina elegans* Ehrbg.—Average number, 14,362. About twice as abundant in 1897. The distribution of this species is somewhat erratic. It has occurred in every month from February through October, but in smaller numbers and sporadically in the colder months. In 1898 its seasonal curve is of characteristic form. It makes its appearance March 15, and is continuously present until the end of September. There is a vernal maximum April 26 of 240,000, but no corresponding autumnal one. In 1898 there are indications of recurrent pulses at brief intervals which coincide in location immediately or approximately with similar ones of *Gonium* and *Pandorina*. These pulses occur March 15 (3,600), April 5 (2,800), April 26 (240,000), June 14 (60,000), August 2 (8,000), August 23 (3,200), and September 20 (2,000). The minima between these pulses in all cases but one fall below 1,000. In 1897 a vernal pulse was not detected, a maximum of 496,000 occurring August 31, and but three minor pulses appearing. In 1896 this species appeared in the plankton on February 20, and remained until the end of August with a month's interruption in May–June. There were no marked pulses, exceeding 15,000, in that year. The absence of the spring flood (Pt. I., Pl. X.) and the disturbed hydrograph of the summer may account for this suppression of development in *Eudorina*. The distribution in preceding years is also irregular.

*Eudorina* begins its seasonal development at temperatures but slightly above 32°, but any considerable growth is not attained until at least 45° has been reached, and the largest pulses on record have been at the close of the period of maximum summer heat at a temperature of 80°, and the vernal pulses have been at 60° or above. The disappearance of *Eudorina* from the plankton in the early fall, about the time that foliage is killed by autumnal frosts, has been constant in the different years.

*Eudorina* is not sufficiently abundant to be of any considerable importance in determining directly the volume of the plankton. It serves as food for many of the rotifers, and is itself frequently parasitized by *Dangeardia mammillata* Schröder, which destroys the cells but leaves the matrix intact. There are times when it is hardly possible to find perfect colonies, and when it is not unusual to see colonies swimming about propelled by one or two surviving cells.

*Euglena acus* Ehrbg.*—Average number, 214,807. Found from the middle of March till the first of November, and most abundantly in late summer and early autumn. It escapes through the silk net readily, and no marked pulses in occurrence appear in the erratic data of the filter-paper collections. It is found in the water-bloom, and is predominantly a warm-water planktont.

*Euglena deses* Ehrbg.—Occurs occasionally in the plankton and water-bloom during summer months.

*Euglena elongata* Schew.*—Average number in 1897, 278,970. It is found irregularly in our plankton and water-bloom from July to October. Originally described from New Zealand.

*Euglena oxyuris* Schmarda.*—Average number, 960,769. Next to *E. viridis* this is the most abundant member of the genus in our plankton. It is abundant during the summer, especially towards its close during low-water conditions, when the water-bloom, in whose formation it shares, is best developed. There is no vernal development, and the fluctuations are but slight in comparison with those of most organisms of the plankton. There is a slight indication of recurrent pulses at intervals of a few weeks. Its optimum temperature lies near that of maximum summer heat, that is, about 80°, though some tendency to run over into autumn months is manifest.

*Euglena sanguinea* Ehrbg.—There are only sporadic occurrences of this species in the plankton. It is found along with *E. viridis* among matted growths of *Lemnaceæ*, and on exposed and reeking mud flats, where it forms patches of bright red color often of large extent. It may be only a physiological condition of *E. viridis*, with which it is always found. It has appeared in the plankton most frequently in September, though found elsewhere throughout the summer.

*Euglena spirogyra* Ehrbg.—Found but once—in October, in the river plankton.

*Euglena viridis* Ehrbg.*—Average number, 1,571,731; from silk collections only 8,653. This is the most abundant of the larger green flagellates in our plankton, and constitutes the greater part of the water-bloom of summer months, when it forms towards four p. m. a livid green scum on the immediate surface of the water. Collections of the silk net give no clue to its abundance and shed no light on its seasonal distribution. The filter-paper collections indicate its presence from March to December, but in numbers only during the warmer period, from May to October. There is no vernal pulse though there are slight traces of minor irregularities, and on September 7, 1897, a single unusual deyelopment of 58,000,000. Its optimum temperatures lie close to the maximum heat of summer months. It is found not only in water-bloom and plankton, but also along shores, on mud banks, and in sequestered pools and bays where temperatures reach 90° and over. Lightly colored and semi-transparent individuals of this and other species of the genus are found frequently in the plankton, suggesting an approach to holozoic nutrition in nature, such as Zumstein ('99) has demonstrated experimentally in *E. gracilis*. *Euglena* is quantitatively one of the most important links in the chain of food relations of the summer plankton, converting nutrient matters in the water, both organic and inorganic, into food for the *Rotifera* and *Entomostraca* of that season of the year. It in a measure replaces the diatoms, some of which decrease in number or disappear during the warmer months.

*Glenodinium cinctum* Ehrbg.*—Average number, 1,360,192. This species is generally present from the middle of March till the end of September, though sporadic occurrences are found in winter months. There is a pulse on March 29 of 4,260,000 at a temperature of 49°, and another August 9 of 25,200,000 at 83°. This small planktont usually escapes through the silk net. It may be that several species have been included, as the conditions of plankton enumeration do not permit close scrutiny of such small organisms, lacking prominent structural characteristics. It seems to be a perennial planktont with a wide range of temperature adaptation, and with a growing period approximating that of the land flora of our latitude.

*Gonium pectorale* O. F. Müll.—This colonial flagellate has been found in the water-bloom in large numbers, especially in the backwaters. It was taken in the river plankton in 1897 and 1898 in May and again in August and September. These pulses coincide in location with those of *Pandorina* and *Eudorina*.

*Lepocinclis ovum* Ehrbg.*—Average number, 401,538; silk 3,719. This species appears in the plankton in April and continues until the end of October, with sporadic appearances in winter months. There is no vernal pulse, and in both 1897 and 1898 maximum numbers, 43,200 and 50,400, occur at the height of midsummer heat in August. In both years there are well-defined recurrent pulses at intervals of three to six weeks to be traced in the silk collections. The optimum temperatures plainly lie near the maximum, that is, about 80°, and the season of growth approximates that of the land flora, being limited to the months of April–September. This is a variable organism, and a number of species have been described in the genus in recent years. Many of these occur in our waters, but no attempt has been made to separate them, since they are based on minute characters.

*Mallomonas plösslii* Perty. and *M. producta* Zach.—These two forms will be treated together, as in my opinion they are merely divergent variants—perhaps seasonal—of a single species. In 1898 *M. plösslii* was found but three times—in June and July—and *M. producta* eight times—from May through September. In 1897 the latter only was recorded, and in September and October. In 1896 *M. plösslii* appeared in July and *M. producta* in April and August. In 1895 *M. producta* alone was recorded, and that in November. The data are hardly sufficient for generalization, but so far as they go they indicate that *producta* is more prevalent in late summer and autumn and *plösslii* in early summer, the more attenuate form (*producta*) in the warmer season.

Bütschli ('80–'89) has intimated that there may be some genetic connection between *Mallomonas* and *Synura uvella.* Certain features of its occurrence in our plankton lend their support to this view. *Synura* in our waters is a winter planktont, with December and February or March pulses. *Mallomonas* is a summer planktont, making its first appearance during the time of the decline of *Synura*, and when many of the colonies of the latter are breaking up into their individual zoöids. Again, the differences in structure and size between the two genera are quite superficial, and might result from the growth attending the free life of a *Synura* zoöid and its preparation for sporulation. It is a noticeable phenomenon that the *proportion* of sporulating individuals of *Mallomonas* in the plankton is exceptionally large among all plankton organisms. "Free cells" of *Synura* are plainly referable to that genus by their resemblance, and by the fact that they are often united in clusters of several individuals forming fragments of disintegrating colonies. It may be that some reproductive phase, as conjugation, intervenes between the free-cell condition of *Synura* and the *Mallomonas* stage, and that the relatively smaller numbers of the latter are due to the infrequency of this process. While the features of seasonal distribution, structure, and sporulation thus suggest the possibility that *Mallomonas* is a free zoöid stage leading to sporulation in *Synura*, they do not demonstrate it, and the genera must stand *in statu quo* until breeding experiments shall clearly demonstrate the full life-cycle of *Synura*.

*Pandorina morum* Bory.—Average number, 6,957. In 1898 this organism was about half as abundant as *Eudorina*, but in 1897 it more than equals it. On account of the small size and the motility of the colonies many of them escape through the silk, so that it is not so adequately represented in silk-net collections as *Eudorina*. It is probably the most important quantitatively of the *Volvocidæ* in our plankton. It occurs from April to October, with a few sporadic appearances in March and up to January. Its greatest growth occurs from May to October. There is no predominant vernal pulse in 1898, but a series of smaller ones culminating May 3 (48,400), June 14 (60,000), July 26 (63,200), and August 30 (3,200),—all upon declining floods (Pt. I., Pl. XII.) and coincident with pulses of other *Volvocidæ*—*Eudorina* and *Gonium*. In 1897 its seasonal distribution was also similar to that of these genera, exhibiting a maximum pulse August 31 of 638,000 at 80°. In 1896, a year of interrupted hydrograph (Pt. I., Pl. X.), *Pandorina* attained no marked development. Its optimum temperatures lie at and above 60°, and its larger pulses appear during the season of maximum temperature, that is, at about 80°. *Pandorina* does not attain any marked autumnal growth, but declines in September, and as a rule disappears in October. The period of its growth thus lies within that of the land flora.

As in *Eudorina*, so also here, parasitism by *Dangeardia mammillata* is of frequent occurrence. *Pandorina* is an important element in the food of summer rotifers such as *Brachionus*.

*Peridinium tabulatum* Ehrbg.*—Average number, 3,875,769; silk, 3,711. This is a perennial planktont, having been found in every month of the year. Its principal development is, however, reached during warmer months, from May till September. In 1897 the maximum pulse of 172,800 was on August 10, and in 1898 one of 66,800 fell on July 26, the temperatures being 81° and 89° respectively. The only exception to this predominance in warm months is an isolated pulse of 2,400 which developed on the declining flood of February, 1899 (Pt. I., Pl. XIII). The absence of any autumnal development of this species is noticeable. Its optimum temperatures lie close to the summer maximum (80°), and though perennial, its occurrences at other seasons than late spring and summer are irregular and its numbers few. Its seasonal distribution in German lakes, as reported by Apstein ('96), is similar to that in the Illinois River. The *Peridiniidæ* play but an insignificant part in the plankton of the Illinois River.

*Phacus longicaudus* Ehrbg.*—Average number, 61,153; silk, 3,031. This species in 1898 made its first appearance in the plankton on March 23 and continued till November 15. The species is small enough to escape through the silk net, and the data from such collections do not fully express its seasonal fluctuations. There is no marked vernal pulse, and there are traces of but a few small ones during the summer, the largest in 1898 being one of 35,200 on September 27. The distribution in previous years is much the same. A well-sustained development throughout the warmer months—save when rising floods, as that of May, 1898, reduce the numbers—indicates that the optimum temperature for the species approaches the summer maximum (80°). There are almost no occurrences below 45°. This is the most abundant member of the genus in our plankton, but it is not quantitatively an important element therein.

*Phacus pleuronectes* Nitzsch.*—Average number, 450,000; silk, 298. It is less abundant (from one fifth to one tenth) than *P. longicauda* in the catches of the silk net but apparently much more abundant in the filter-paper collections, which may be due in part to its smaller size and greater tendency to escape through the silk in the collections of the net. Its occurrences are even more closely limited to summer months—from June till September. There is no vernal development, and the largest numbers occur during the period of maximum heat. Pulses are but feebly defined. It is also a summer planktont.

*Phacus pyrum* Ehrbg. was found but once—on August 10, 1897.

*Phacus triqueter* Ehrbg. occurred in small numbers during July and August, 1897.

*Platydorina caudata* Kofoid.—Average number, 17. In 1898 this interesting new genus of the *Volvocidæ* was found in the plankton only in the latter part of July. In 1897 it was much more abundant (average number, 21,963) and ranged from July 14 to October

12. There was a pulse on July 21 of 18,400 and another on September 7 of 600,000. In previous years the occurrences were scattering, but confined to July, August, and early September. It is evidently a summer planktont, whose optimum temperature lies near the maximum attained by our waters. No record of occurrence below 60° was made. The smaller and younger colonies escape readily through the silk net. Its pulses in 1897 coincide very closely with those of *Gonium*, *Pandorina*, *Eudorina*, and *Pleodorina*.

*Pleodorina californica* Shaw.—Average number, 11. In 1897 this species, in common with other members of the family, was much more abundant than in any other year of our work, stable conditions of low water with the accompanying sewage contamination seeming to favor its development. The earliest record for *P. californica* in the plankton is May 18, 1896, at 71°. This was a year of lower water and higher temperatures than usual in spring months (Pt. I., Pl. X.). In other years *P. californica* did not appear until June or July. It continues into September, the latest record in 1895 being October 2. In 1897 there were pulses on July 21 (5,600) and September 7 (4,000). The occurrences at other seasons are too scattered to trace the seasonal fluctuations, but there is a well-defined predominance during the period of maximum heat. This is evidently a summer planktont, whose optimum temperature lies near 80°.

*Pleodorina illinoisensis* Kofoid.—Average number, 6,917 in 1897. This is somewhat more numerous than the preceding species, and its range of occurrences is quite similar. Its maximum pulse in 1897 (180,000) is on August 31, a week earlier than in other members of the family. These pulses of the *Volvocidæ* occur (Pt. I., Pl. XLIV.) in a depression of nitrates and just prior to the volumetric pulse of September, 1897. This pulse is doubtless built up partly at their expense. Their decline in numbers corresponds with its rise. This is also a summer planktont, and was not recorded below 71°.

*Salpingœca brunnea* Stokes.*—This species was not recorded in 1898. Average number in 1897, 1,887,356. It occurred on May 25 and July 21, dates of culmination of pulses of *Melosira granulata* var. *spinosa*. In August–September a pulse occurs, culminating September 7 at 47,250,000—a week after the culmination of a *Melosira* pulse. In 1896 (silk collections only) it was present throughout most of the summer, attending only approximately the suppressed and interrupted pulses of *Melosira* in that year of disturbed hydrograph. It has been recorded from the latter part of April till the middle of September, and, as a rule, above 60°. This beautiful little choanoflagellate is sessile upon the filaments of *Melosira*, principally upon the variety *spinosa*, and but rarely upon *M. varians* or other planktonts such as *Pediastrum*. It is often associated with *Bicosœca lacustris* and is usually found upon the sides of the filaments, the bowl of the transparent brownish lorica being closely sessile upon the diatom. In one instance a lorica was found upon the corner at the end of the filament. The lorica had adapted itself to this novel situation by an angular indentation fitted upon the corner of the diatom.

*Syncrypta volvox* Ehrbg.—Average number, 625. This species has a definite and somewhat unusual seasonal distribution. In 1898 it was found from March 1 to April 12, and reappeared November 8, attaining a maximum of 13,500 on December 6, and of 43,000 on January 1, declining then to 800 and rising on February 14 to 4,800, and subsequently disappearing in the flood waters of March. It was not recorded in 1897. In 1895 it appeared September 27 and continued for a month, reappearing in February and March, and not occurring after April 10. It has attained its largest development at minimum temperatures under the ice—43,000 January 3, 1899, at 32.7°. The greater part of its occurrences in 1898–1899 lie very near this temperature, and but three in all the years lie above 50°. It is *par excellence* a winter planktont, or at least a cold-water one.

Its occurrences in 1895–1896 lie near the beginning and the close of the seasonal pulse of *Synura*. In 1898–1899 the pulses of *Syncrypta* coincide in location with or immediately follow those of *Synura*. The resemblance of *Syncrypta* to small colonies of *Synura* is striking, and this fact combined with the relation of their seasonal fluctuations raises the query if *Syncrypta* may not be an encysting stage of the *Synura* colony. Its life history should be fully worked out.

*Synura uvella* Ehrbg.—Average number of colonies, 8,463. The seasonal distribution of this chrysomonad flagellate is somewhat similar to that of its near relative *Syncrypta*. It is a perennial, though predominantly cold-water, planktont. It appears in the December plankton of 1894, but was exterminated from the channel plankton taken in the following February by the stagnation attending the long-continued ice blockade. It reappears in April, and again disappears promptly, but does not return until September 12, and not in numbers until October. There are pulses November 20 (506,800) at 42.8°, and December 30 (362,520) at 36.5°. The December pulse is followed by a decline, with a rise during February to a well-sustained maximum during March, approaching 400,000, and at from 35° to 48°. The decline follows in April, and there are only isolated occurrences in small numbers at irregular intervals during the summer. Continuous occurrence begins again in September, and numbers rise rapidly in October. There is a pulse of 542,699 on December 3 at 32.2°, and another on March 22, 1897, of 159,500 at 43.8°. *Synura* is very rare indeed in the summer of 1897, and in the prolonged low water, sewage contamination, and higher temperatures of the unusual autumn of that year it does not reappear continuously until October 26, at 59°, and does not exceed 1,000 until December 7, at 32°. There is a low maximum of 98,700 on December 14 at 36°, followed by a decline during the rising flood of January–March, 1898. The slight cessations in the flood invasion (Pt. I., Pl. XII.) in January and in the second weeks of February and March produce prompt responses in immediate rise in numbers in *Synura*. Finally, a low maximum of 320,600 is attained upon the crest of the March flood, on the 29th, at 49°. This is followed by a decline during April and a few scattered appearances during the summer. *Synura* returns at the end of October and rapidly mounts to a pulse of 1,999,500 on November 29 at 35° with the first decline of the November overflow (Pt. I., Pl. XII.). A second pulse of 2,764,800 on December 20 at 33°, under the ice, gives way to a decline to 51,600 towards the end of January, 1899, during rising water. On February 14 another pulse (348,800) appears at 32.5°, under heavy ice, and declines again in the sudden flood of the last days of February, but recovers quickly with a maximum pulse of 898,800 on March 7 at 32.8°. Within a fortnight this falls to the low level of 9,800, but its further history was not followed.

From these data it is evident that in our waters at least *Synura* is limited to the months from October to April, except isolated and irregular occurrences of small numbers during the summer. Its optimum temperatures lie below 50°, and its greatest development has taken place in minimum temperatures under the ice. Rising floods and disturbed hydrographic conditions tend to reduce its numbers or to suppress its development, while declining floods initiate increase in numbers and favor the appearance of pulses. A "late" autumn delays the appearance of *Synura*.

Not only are colonies of *Synura* found in the collections, but at times large numbers of free cells make their appearance. These are released by the breaking up of colonies, and occur in all degrees of isolation. It seems to be a natural phenomenon, and occurs most abundantly with or immediately after the crest of the pulse. Thus the pulse of December 29 (1,999,500 colonies) was attended by 21,600,000* free cells on that date. A week later there were 1,693,500 colonies and 57,600,000 free cells. There are in the records several instances of meteoric increases of free cells at other times than at those of apparent pulses. It does not seem possible from the data at hand to determine whether this is due to environmental influences or to the accidents of collection and subsequent handling. In the discussions of *Mallomonas* and *Syncrypta*, suggestions have been made that these organisms may be stages in the life cycle of *Synura*. *Synura* is the largest and by far the most important synthetic organism of the winter plankton. It shares appreciably in the winter volumetric pulses—as, for example, those of December, 1898 (Pt. I., Pl. XII.).

Its fluctuations do not seem to produce any marked effect upon the nitrates, possibly because the latter are present in excess of the needs of *Synura*. In the winter of 1898 nitrates are high, 1.25 parts per million with the pulse of 1,999,500 colonies on November 29, but decline rapidly to .1 on December 13 with a fall of *Synura* to 78,000. On December 20, *Synura* rises to 2,764,800, but the nitrates rise only to .35. It is evident that the nitrates are not the only factor regulating the fluctuations of *Synura*.

Marsson ('00) reports *Synura* as abundant in the winter plankton of lakes about Berlin, and Brunnthaler ('00) finds it in the winter plankton of the Danube. There is, however, no recorded instance in which *Synura* forms so prominent a part of the plankton of a body of water as it does of that of the Illinois River. It may be that a closer analysis than has yet been given the potamoplankton of other streams will reveal its prominence there also. It is present (Kofoid

'95) in the *summer* plankton of the Great Lakes at temperatures 15° to 20° below the summer maximum of the Illinois River.

*Trachelomonas acuminata* Schmarda.*—Average number, 1,094,-615; silk, 873. This species appears in the plankton in April or May and continues into October or November. There is no vernal pulse, and the data are too irregular to trace the seasonal fluctuations. The greater numbers occur during the period of maximum heat. Excepting a single occurrence in February, this species has been found only above 40°, and its period of continuous appearance from May to October lies above 60°. It is evidently a summer planktont.

*Trachelomonas hispida* Stein.*—Average number, 1,002,115; silk, 1,251. This is a perennial organism, found in every month of the year but in larger numbers during the warmer months. It was more abundant than usual in the winter of 1897–98 following the low water and unusual development of the previous fall. There are no large pulses in 1898, but in 1897 there is indication of a vernal maximum on April 27 and an autumnal one of 85,500,000 on September 7. The data are too irregular to trace the seasonal fluctuations in detail. There is no doubt, however, from the evidence at hand that this is a predominantly warm-water planktont similar to the other members of the genus.

*Trachelomonas volvocina* Ehrbg.*—Average number, 17,672,692; silk, 7,162. This is the most abundant species of the genus and is found throughout the year in almost every collection. It is most abundant from May to October, during the period of maximum heat. There are no well-defined vernal or autumnal pulses, but recurrent maxima during the summer are to be found in both 1897 and 1898. There are four such pulses in the former year, and in the latter five, as follows: May 17 at 64° (14,400,000), June 21 at 77° (147,600,000), July 19 at 84° (86,400,000), August 9 at 83° (252,000,000), and October 4 at 71.5° (11,700,000). The periods of greatest growth thus lie above 60° and the optimum is near 80°. None of these pulses coincides with a volumetric maximum of the silk-net catches (Pt. I., Pl. XII.). They usually follow these maxima at intervals of one or two weeks—a phenomenon often observed in other synthetic species. It may be explained by the decrease in animals which feed upon the organisms in question. These volumetric pulses are predominantly animal in their composition, and when they decline the organisms upon which the disappearing animals were feeding have an opportunity to multiply with less decimation in their ranks.

This species is one of the most abundant of the synthetic organisms in the summer plankton, and next to *Euglena* is the foremost among the synthetic elements of the food cycle of the plankton. The presence of many light-colored or even colorless forms (forma *hyalina* Kl.) justifies the suspicion that members of this genus, like those of its near relative *Euglena*, adopt holozoic nutrition in the presence of abundant organic matter suitable for food.

This species, as well as the others above listed, is exceedingly variable in the proportions of the lorica, in its color, and in the development of the neck. It is very desirable that its life history and the full limits of its variation be determined before many more new species are proposed in the genus.

In addition to the forms above listed, the following have been noted as present in small numbers in the summer plankton, viz.: *T. armata* Ehrbg., *T. caudata* Ehrbg., *T. torta* Stokes, *T. urceolata* Stokes, and *T. volvocina* var. *rugulosa* Kl.

*Uroglena americana* Calkins.—This species was found in small numbers in July and September, 1897, and in January, 1899.

*Uroglena radiata* Calkins.—This species was found in January, 1896; in April and May, 1897; and in March and April, 1898. There was a vernal pulse of 15,279 on April 29, 1896.

*Uroglena volvox* Ehrbg.—This species was found sparingly in the spring plankton in 1896. *Uroglena* is one of the few organisms which the usual method of plankton collection and preservation fails to keep in fair condition for subsequent indentification. The gelatinous matrix is easily crushed, and debris adheres to it so as to obscure it beyond recognition. Judging from the frequency of *Uroglena* in the living plankton it is very probable that the genus is much more abundantly represented in the Illinois River than the data at hand indicate. The genus seems to prefer the cooler waters of autumn and spring to those of midsummer.

*Volvox aureus* Ehrbg.—This species was found from March to August, but in small numbers and irregularly.

*Volvox globator* L.—This was somewhat more abundant than the previous species, and was found more frequently, especially during

1895 and 1896. It occurred from the first of May till the end of August, but always in small numbers. It is occasionally abundant in backwaters where there is much vegetation.

In addition to the *Mastigophora* above listed there were many individuals belonging to unidentified species. They were as a rule the smaller forms, which are not readily identified in preserved material and under the conditions of plankton enumeration. They constitute about twenty-six per cent. of the total *Mastigophora* enumerated. In silty planktons their number is relatively somewhat larger on account of the difficulties attending the determination of species in such material. These unidentified flagellates occur in every collection, and are somewhat more abundant in the summer months.

### RHIZOPODA.

Average number, 55,364, including filter-paper collections; 23,826 without them. This group of *Protozoa* is numerically of less importance than the ciliates or flagellates, but its quantitative significance is greater than the numbers of individuals indicate. This is due to the relatively large size of the *Rhizopoda*, and also to the fact that plankton collections afford only an irregular and incomplete record of the rhizopodan fauna of any body of water, and give but an imperfect idea of the part which these organisms play in the total economy of the lake or stream. This results from the fact that they are as a rule largely bottom or shore-loving species, and are generally either adventitious or temporary constituents of the plankton.

The seasonal distribution of the total *Rhizopoda* in the Illinois River gives evidence of the adventitious or temporary nature of the contributions of the group to the plankton. There are pulses in 1898 on January 25 (66,388), February 22 (141,524), August 23 (36,800), September 27 (59,200), and November 15 (42,000), all of which appear on rising water and are largely adventitious, their presence in the plankton being due to the disturbances of currents, waves, and the like. There are pulses on May 10 (49,800), June 28 (37,000), and July 19 (28,800) which cannot be traced to any general hydrographic condition. These, as will be suggested in the discussion of the seasonal fluctuations of individual species, are probably due to the temporary adoption of a limnetic habit on the part of some of the rhizopods, or to the appearance of limnetic forms, varieties, or species—according to the systematic value placed upon these eulimnetic individuals. I am inclined myself to regard them as seasonal forms of species which are predominantly of the bottom or littoral fauna, which have multiplied rapidly under the stimulus of abundant food. Owing to this fact, to the storage in their tissues of the products of metabolism, such as gas and oil vacuoles which tend to lighten their specific gravity, and to the frailer structure of their shells under conditions of rapid multiplication, they abandon their customary benthal or littoral habitat and assume temporarily a limnetic distribution in the plankton where they continue to find abundant food. Their appearance here under these circumstances is a result of their physiological condition, and with its cessation they decline, as shown by their pulse-like occurrences.

Whatever the systematic valuation placed upon these limnetic forms may be, there is no doubt of their occurrence. They have appeared in every year of our operations, but were most prevalent in 1897, a year of most stable conditions, and also in the quieter backwaters, and on the declining spring flood or June rise when hydrographic conditions are less catastrophic than those of early flood stages. In 1897 there was a pulse of 68,400 (silk-net only) on August 8 and another of 1,268,400 on September 7, both in stable conditions and almost exclusively of limnetic types, differing in this respect from the pulse of 141,524 on February 22, 1898, which was predominantly of an adventitious character, resulting from the flood of that period (Pt. I., Pl. XII.). The contrast in the numbers of *Rhizopoda* in the plankton during warm and cold seasons of the year is very striking in 1897. The average per $m^3$, per collection from May 1 to October 1, that is, above 60°, is 161,045, omitting all filter-paper collections, while in the seven months of lower temperatures this average is only 4,771. During the warmer period the June rise was the only hydrographic disturbance (Pt. I., Pl. XI.) to which any adventitious increase might be attributed. This contrast is less evident in 1898, when the summer hydrograph was more disturbed. These larger numbers during warmer months may be attributed in part to the greater numbers of the *Rhizopoda* in their littoral habitat, and in part, doubtless, to the fact that at low water the shore and bottom fauna are brought into more intimate relation with the plankton, and in the river the disturbance of these regions by current, waves, seines, boats, and fish make relatively larger contributions at low-water stages to the diversification of the plankton. In addition to these factors, however, there is abundant indication that many individuals assume during the warmer months a eulimnetic habit, and that some of the *Rhizopoda* become, for the time being at least, typical, though temporary, planktonts.

It naturally follows that in so far as the plankton is concerned, the *Rhizopoda* exhibit a seasonal preference for the warmer months above 60°. Maximum numbers were attained only at the higher temperatures save in those instances where they attend winter floods. In a measure the seasonal distribution of the *Rhizopoda* in the plankton reflects that of the group in its normal habitat; but at the best the picture is incomplete.

The *Rhizopoda* have important relations in the economy of the plankton. They feed upon diatoms, desmids, the smaller algæ, and even the chlorophyll-bearing *Mastigophora* such as *Trachelomonas* and *Carteria*. Their occurrences in the plankton do not exhibit any striking correlation with those of the groups named. The great pulse of September 7, 1897, for example (Pl. II.), lies in a depression of the diatoms and coincides with pulses of *Chlorophyceæ* and *Mastigophora*, and that of August 10 (68,400) exhibits a similar relation, the diatoms rising the following week as the *Rhizopoda* fall. In 1898 the pulse of *Rhizopoda* on June 28 of 37,000 (Table I.) culminates a fortnight after that of the diatoms and *Chlorophyceæ* and a week after that of the *Mastigophora*. It thus is intercalated between the June and July pulses of these chlorophyll-bearing organisms (Pl. II.). The *Rhizopoda* pulse of July 19 (28,800), on the other hand, occurs with the coincident pulses of the three groups named (Pl. II.). The immediate diluent effect of flood waters upon the plankton combined with their tendency to increase the number of adventitious *Rhizopoda* results at times in the intercalation of their pulses with those of the chlorophyll-bearing organisms whose relative numbers are reduced by the dilution. The data evidently do not afford any adequate solution of the intercalations of the *Rhizopoda* with other organisms.

The *Rhizopoda* are very frequently found in the digestive tract of limnetic rotifers, but I have never noted the *Entomostraca* feeding upon them. They are important elements in the food of young fish (Forbes, '80) such as the *Catostomidæ* and some of the *Siluridæ* and minnows. I have found them in great abundance in the intestine of the adult gizzard-shad (*Dorosoma*), and in the contents of the digestive tract of the German carp (*Cyprinus carpio*).

In the pages which follow, the seasonal distribution, or occurrence in the plankton, of thirty-one *Rhizopoda* is discussed, and the presence in the plankton of the Illinois of twenty-eight other rhizopodan forms which have been recognized by other writers as of specific rank is noted. This by no means exhausts the rhizopodan fauna of the environment which was the field of this investigation. A continued study of the plankton itself would doubtless greatly extend the list of adventitious forms from the shore and bottom, and a more careful analysis of the variants, especially in the *Difflugia globulosa-lobostoma* group, would still further increase the richness of the fauna from the systematic point of view. Hempel ('99) lists sixteen species from this locality, and Penard ('02), in discussion, remarks: "Une pareille pauvreté dans une région riche en organismes de toute nature, est une impossibilitié matérielle." However, neither Hempel's paper nor the present one pretends to give a full account of all the *Rhizopoda* of the region. He dealt *largely* with *plankton* collections, and the present paper deals with them exclusively.

There is but little in plankton literature which gives with any fulness the seasonal distribution of the *Rhizopoda*, or indicates that they are of any considerable importance in the economy of the plankton. The importance which they acquired in the plankton of the Illinois is no doubt in part due to the nature of the environment with which we are dealing. The somewhat sporadic and meteoric character of their appearances in our waters leads to the inference that full seasonal analyses of the plankton of other bodies of water at brief intervals may reveal a greater prevalence of the *Rhizopoda* in the plankton than has hitherto been detected.

### DISCUSSION OF SPECIES OF RHIZOPODA.

*Amœba limax* Duj.—This was frequently abundant in the water-bloom of midsummer, but was not identified in the plankton collections.

*Amœba proteus* Rösel.—Average number, 342. The individuals here assigned to *A. proteus* include those taken in our plankton which belong to the type of *A. radiosa* Ehrbg., a type which presents no distinctions sufficiently well-defined to separate it specifically from the first-named form. It seems probable that *A. radiosa* includes small individuals of *A. proteus* which are not, at the time of observation, creeping upon a substratum; that is, they are limnetic, floating free with filamentous pseudopodia characteristic of that condition. Verworn ('97) has shown that *A. proteus* takes the *radiosa* form in weakly alkaline solutions. Pond water rich in algæ may have an alkaline reaction (Knauthe, '98) in bright sunlight. Larger individuals, distinctly referable to the *A. proteus* type when taken in the plankton, possess at times the slender pseudopodia of the *A. radiosa* type as well as the blunter ones characteristic of the *A. proteus* form. I see no valid reason for separating the two as distinct species. Most of the *Amœba* recorded from the plankton collections belong to the *A. proteus* type, the smaller ones belonging to the *radiosa* type probably escaping through the meshes of the silk net.

This species was found in 30 of the 180 collections examined, being observed in all months of the year except May, November, and December. The conditions attending its occurrence suggest that it is not, habitually at least, an active planktont at all seasons of its occurrence, but rather a tycholimnetic member, an invader from the littoral or bottom fauna, or a temporary accession during the warmer months. In the first place, both the number of occurrences and the numbers of individuals found are small, and the seasonal distribution, plotted from the data of the collections of the five years, is exceedingly irregular. Furthermore, 17 of the 30 occurrences happened on rising floods, when the fauna of the bottom and shore of both the river and its tributaries is most mingled with the plankton. Further evidence of the agency of floods in introducing *Amœba* into the plankton is brought to light by a comparison of its occurrences in 1897 and 1898. As shown by Plates XI. and XII., Part I., the hydrograph of 1897 is much less irregular than that of 1898, the latter year exhibiting repeated fluctuations in level due to floods. As a result we find *Amœba* occurring relatively (to the number of collections) almost twice as often in 1898 as it did in 1897. It may also be significant that *Amœba* was not found in November and December, months of unusual stability in river levels. There is, however, a suggestion in the data of distribution (see Table I.) that *Amœba* may become an active member of the plankton during the warmer seasons, like other *Rhizopoda*, as a result, perhaps, of the formation of gas or oil vacuoles in its protoplasm. Of the 30 occurrences, 21 fall between April 19 and October 17, with water temperatures of 58° and 56°, respectively. Of these 21 occurrences in warm waters but 8 accompany flood invasions, while all of the 9 occurrences during the colder months are in connection with such disturbances. Finally, the maximum number per cubic meter (6,400) was found July 21 in clear waters, free from the debris of flood invasion. In conclusion, it seems probable that *Amœba* in warmer seasons of the year (above 56°) may adopt a limnetic habit. There is, however, the possibility that local and minor disturbances of the water due to current, waves, etc., are the occasion of its presence in the plankton in the absence of flood conditions. Jennings ('00a) reports both *A. proteus* and *A. radiosa* in the open water of Lake Erie.

The range of temperature of river water in which *Amœba* was found was from 32° to 89°—the full extremes observed by us in the river at Havana. The temperature at the maximum occurrence, July 21, 1897, was 82°. It is perhaps significant that 14 of the 30 occurrences of *Amœba* were between June 21 and September 6, the period of maximum heat, the river averaging almost 80°—apparently the optimum temperature for the occurrence of *Amœba* in the plankton in this locality. The relative numbers of individuals found in the various collections of the five years are too irregular to suggest any conclusions as to a seasonal cycle.

*Amœba verrucosa* Ehrbg.—Average number, 19. This species was found but three times in the plankton, once each in May, August, and September, occurring but singly, and in each case in flood waters. It is apparently a tycholimnetic member of the plankton. The temperature limits of its recorded occurrence in the plankton were 58° and 82° respectively.

### *Arcella.*

This genus is represented in the plankton by four species and two varieties which, like most of the *Rhizopoda*, are exceedingly variable, grading in some instances into each other by occasional individuals which present intermediate characters. The majority of the individuals were taken in a living condition, though many empty shells were found. The conditions of the examination of the plankton and the opacity of many of the shells made it impossible to distinguish the dead shells in all cases. The records include many dead shells.

*Arcella costata* Ehrbg.—Average number, 48. For the purposes of this paper I have included here all those individuals which possess an angular or ribbed shell. Leidy ('79) refers such forms to *A. vulgaris.* Individuals of this type are rare, occurring infrequently and in small numbers. It was recorded but 18 times in the 180 collections, and the largest number per cubic meter was only 1,187. As in the other species of the genus, the warmer months are favored, fourteen occurrences falling in June–September in water at 70° or above. The other four records are one each in April, October, November, and December. The seasonal range of this form in the plankton thus falls in the main within the period of the maximum abundance of *A. vulgaris*, of which species it may be but a variant.

*Arcella discoides* Ehrbg.—Average number, 972. This prevalent species is not in all instances easily separated from *A. vulgaris.* Indeed, even Leidy ('79) states that it graduates into *A. vulgaris*, and that he views it as the variety of this species in "which the shell presents a greater proportionate reduction in height compared with the breadth." In the enumeration of our plankton catches, the larger, flatter, and unornamented individuals have been referred to this species. Both the brownish and the hyaline forms should probably, for reasons hereafter given, be included here, and they are so grouped in the present discussion. Thus considered, *A. discoides* is the most abundant member of the river plankton belonging to this genus, including two thirds of all the individuals observed.

This species occurred in almost two thirds of the collections, having been recorded in 115 of the 180, and more frequently and in larger numbers in the latter half of the five years than it was in the earlier period. This is in part explained by the unusual fluctuations of the river levels in 1898, during the maximum summer occurrence of the species. Like the other species of the genus, *A. discoides* has a period of maximum occurrence in the latter part of summer, as is shown in Table I. Of the 115 occurrences, 55 were in

June–September, in water at or above 70°, while in the remaining eight months there were but 60 occurrences. This contrast is heightened by the ratio of occurrences to the total number of collections, which in the period from June to September inclusive is 55 to 68 and in the remainder of the year only 60 to 112. The number per cubic meter is also higher during this warm period, averaging for a single occurrence 1,376 to 1,028 for one in the remainder of the year. The average for the colder months falls to 850 if the large accessions attending the floods of February and November are omitted in the totals. The same causes efficient in determining the summer maximum in other *Rhizopoda* of the plankton are doubtless operative here, and as in *A. vulgaris* the impetus of the summer increase is carried over into the autumn, causing a slight increase in numbers as compared with the numbers at corresponding temperatures in the spring months. It seems probable that high temperatures favor its occurrence in the plankton, not, however, directly, but because of greater abundance of food under those conditions, greater metabolism, and the storage of the products as oil or gas vacuoles which tend to lower the specific gravity and thus to bring the animal into the plankton.

The adventitious occurrence of *A. discoides* in the plankton is shown by the fact that 45 of the 115 occurrences are with rising flood waters. The greater part of them lie in the colder months; in fact, nine tenths of the occurrences between October and May are correlated with flood movements. For reasons above given, however, *A. discoides* may be regarded as temporarily adopting a limnetic habit during warm months as a result of its physiological condition; at least many individuals of the species exhibit this habit during the warmer months. The data do not indicate that the open water is at any time the center of distribution of the species.

There are no indications of recurrent pulses in the species and, as might be expected in case of adventitious planktonts, but little evidence of a characteristic seasonal distribution. There is some evidence that the summer is the period of most active multiplication, and that an exceedingly transparent and hyaline form otherwise resembling *A. discoides* is the young of this species. In 1898 separate records were kept of the two types with the result that they were about equally abundant—24,159 and 26,387 for the brown and hyaline types respectively.

With but few exceptions the seasonal distribution exhibited by the hyaline form was very similar in time and numbers to that of the brown form. Both occurred more frequently and in larger numbers in the warmer months, and irregularly and in small numbers in the colder waters. Both entered in larger numbers with flood waters. The differences though slight are suggestive. The hyaline form was less frequent than the brown both in occurrences and numbers during cold weather, and summer floods sometimes brought a relatively larger number of the hyaline type. These are conditions that might be expected if the latter is only the young (that is, the daughter organism occupying the new shell after fission of the occupant of the old) of *Arcella discoides*. In warmer months food is more abundant and, presumably, fission more frequent. For this reason the young individuals abound at that time. Owing to the difference in the specific gravity of the two, the hyaline type is more readily transported by flood waters. Though not conclusive, the data here presented seem to favor the view that the hyaline form is only a stage in the life history of the individual *Arcella discoides*.

The species *A. artocrea* Leidy and *A. polypora* Penard occur also in our waters, but were included with *A. discoides* in the enumeration. Typical representatives of these species are not, however, present in any numbers

*Arcella mitrata* Leidy was found but once—on Aug. 1, 1895, in small numbers, at 78.5°.

*Arcella stellata* Perty.—Under this designation are included only those individuals which have well-defined prolongations on the margin of the shell. Only a single occurrence in small numbers (48 per cubic meter) was recorded for the typical *A. stellata* — July 29, 1895, at a temperature of 75.5°.

*Arcella vulgaris* Ehrbg.—Average number, 1,098. This species is somewhat more abundant than *A. discoides*, but occurred in fewer collections. It is a somewhat common planktont, whose seasonal distribution exhibits some irregularities attributable in part, as in the case of other members of the genus, to flood conditions. It was found in 61 of the 180 collections examined, and in approximately one third of those made in each year, excepting in 1894, when it was not recorded, and in 1898, in which year it was found in about half the collections, the river levels for this latter year being subject to more than the usual disturbance.

*Arcella vulgaris* is found throughout the whole year, with a marked predominance of occurrences during the warmer months, June to September inclusive, for during this period, in which a total of 68 collections were made, this species was found in the plankton 34 times. If the month of October be included, the ratio is 44 occurrences in 83 collections, while in the remaining 97 collections, from November to June, only 17 occurrences were recorded. Of the 10 occurrences in October, 7 were in water at or above 55°. The season of frequency in the plankton thus ranges from June through October. In both frequency of occurrence and in numbers of individuals (see Table I.) there is an apparent maximum in August, preceded by an increase in June and July and followed by a decline in September and October. *Arcella vulgaris* thus seems to be a late summer planktont. The continuance into October may in part be due to the temperature conditions above cited, and perhaps also to constant seining of the river by fishermen in the low-water stages at that time, causing repeated disturbances of the bottom and shores, where *Arcella* habitually lives. This maximum frequency of *Arcella* during the warmer months in the plankton is, however, probably due to the formation of gas or oil vacuoles in the plasma under the conditions of higher temperatures. Their flotation is thus facilitated, and they become, in a way, semi-active but temporary planktonts.

That floods are also in part responsible for the presence of *Arcella* in the plankton is evident from the fact that 32 of the 61 occurrences come with rapidly rising waters, or shortly after rapid rises, during the interval of rapid decline. The larger numbers of individuals also appear in flood-waters, occurrences of more than 1000 per cubic meter happening 10 times with floods to only 4 in more stable conditions. The maximum occurrence, 25,272 per cubic meter, came with the flood of February, 1898, indicating the presence of this species in large numbers, even under winter conditions, in some local environment tributary to the flood plankton.

The average number per cubic meter in the 61 collections containing *Arcella* was 1,260; and the maximum, 25,272, as above noted. This species occurred in only 10 collections in stable conditions of the river, when the temperature of the water was below 55°. The average number of individuals in these cases was, however, only 230 per cubic meter as against 1,443 when the temperature was above 55°, or, if below, when floods prevailed. The seasonal and numerical distribution of occurrences and individuals alike point to the agency of floods and higher temperatures in the introduction of *Arcella* into the plankton from its usual habitat, the bottom and the shore.

This species occurred in water ranging in temperature from 32° to 89°. Being a bottom form, the plankton data do not afford a satisfactory basis for determining its true seasonal distribution and optimum temperature. The maximum number found, 25,272, was in water at 32°; but this was an isolated occurrence in a flood, and serves only to illustrate the irregularity of distribution in the plankton of tycholimnetic organisms.

*Centropyxis aculeata* Stein.—Average number, 570. This species has appeared in collections in every month of the year, but its sequence is frequently interrupted and its numbers are quite irregular. Practically without exception all the larger occurrences attend rising flood waters. It is evidently adventitious at all seasons of the year.

*Centropyxis aculeata* var. *ecornis* (Ehrbg.) Leidy.—Average number, 604. In former years this species was less frequent than the preceding species. Its appearances in the plankton tend to coincide with those of *C. aculeata* (Table I.), and are doubtless due to the same causes. Thus in the February flood of 1898 there is a pulse of 12,636 of *C. aculeata* and one of 9,477 of var. *ecornis*. *C. lævigata* Penard seems to be identical with this variety. The data concerning both *C. aculeata* and its variety *ecornis* are too irregular to throw any light on the seasonal cycle of these adventitious planktonts.

*Cochliopodium bilimbosum* (Auerbach) Leidy.—Average number, 1,384. This species was found in the plankton during 1898 in irregular numbers in 27 of the 52 collections. The distribution of the occurrences affords indubitable proof of their close dependence upon flood waters. In 15 of the 27 cases *Cochliopodium* appeared with a rising river, and in *all* but 6 cases, in periods of considerable movement in river levels (cf. Table I. with Pl. XII., Pt. I.), such as the rising flood of January and February and the repeated minor fluctuations of August and the following months. The year 1898 was one of unusual irregularity in the hydrograph (Pt. I., Pl. XII.), especially at the lower stages of the river, at which times this rhizopod appeared most frequently. Its maximum occurrence, 20,898 per cubic meter on Jan. 25, accompanied a rise of 0.6 of a foot in 24 hours. At other times the numbers range from 100 to 8,000 per cubic meter, their irregularity affording additional ground for regarding this species as an adventitious planktont.

*Cochliopodium* was present in water ranging from 32.1° to 89°, the maximum number observed being found in water almost at the freezing point, when the river was full of running ice. That this is the optimum temperature for this organism is not, however, to be inferred, since, as has been shown above, this species is adventitious in the plankton. Plankton collections do not afford adequate data for determining the seasonal cycle of the organisms habitually living upon the bottom. This species was not found, though careful search was made for it, in the winter collections of 1899. Its absence from the records of years previous to 1898 may in part be due to a failure to observe it in the silt-polluted collections in which it is most apt to occur.

*Cyphoderia margaritacea* Ehrbg.—Average number, 198. This species has occurred in every month but February. In 1898, the majority of the occurrences and three fourths of the numbers appeared between May 1 and October 1 at temperatures above 60°. It was never abundant at any time, though there is this indication of its increased numbers during the warmer season. It is not an important element in our plankton. Apstein ('96) found it somewhat irregularly in the plankton of German lakes. In our waters it exhibits no marked dependency upon floods for its presence in the plankton, though it is probably capable of assuming the limnetic habit in the warmer season.

*Cyphoderia trochus* Penard appeared occasionally with the preceding form, from which it is distinguished by its conical horn on the fundus and by its larger scales.

### *Difflugia.*

This genus is the most abundant one of the *Rhizopoda* in the plankton of the Illinois River, and is a factor of quantitative importance in its economy. It includes a number of forms notorious for their variability and for the difficulty with which specific distinctions can be applied. I shall discuss the species as they were enumerated, and shall correlate my work with Penard's ('02) recent elaborate analysis of the species so far as I can with the aid of my notes in the absence of the collections. Opinion as to the validity of the species is expressly withheld excepting in those instances in which it is formally stated.

*Difflugia acuminata* Ehrbg.—Average number, 315. This species has occurred in every month of the year and in 83 out of 180 collections. In 1898, two thirds of the occurrences and three fourths of the individuals were taken between May 1 and October 30, at temperatures above 70°. In this year there are six recurrent pulses from June to November, but all but one of these are found on rapidly rising flood waters, and they bear no constant relation to the pulses of diatoms previously noted, with which in some instances they are intercalated, though this is not regular or constant. Similar tendencies to appear with floods and in greater numbers and more frequently in summer can be detected in records of other years. It was more than twice as abundant in 1896—a year of interrupted hydrograph (Pt. I., Pl. X.)—as in 1898. This is one of the larger and heavier rhizopods, and its occurrence in the plankton is doubtless adventitious, due to floods and currents, and its greater numbers and frequency in the summer may result from its greater abundance at that season in its natural habitat, the shore and bottom, and perhaps, also, from its lighter specific gravity during the warmer season. An illustration of this appears on the rising flood of June, 1897, when the maximum number recorded (10,000 per $m.^3$) occurred.

The shell of this species is exceedingly variable in size, constituent particles, and proportions. A number of forms separated by Penard ('02) and others as distinct species were grouped under *D. acuminata* in the enumeration. The greater number of these belong to the type designated by this name by Penard ('02). *D. acuminata* var. *inflata* Penard and the somewhat similar *D. elegans* Penard are not uncommon. *D. acuminata* var. *umbilicata* Penard, *D. elegans* var. *teres* Penard, *D. curvicaulis* Penard, *D. lanceolata* Penard, and *D. scalpellum* Penard occur also, but are rare.

*Difflugia bicuspidata* Rhumbler.—Average number, 76. A separate record was kept of this bicuspid type in the later years of our collections. Penard ('02) regards it as a synonym of his *D. elegans*, though it would seem to be as worthy of specific distinction as many other variants to which he accords this rank. It varies greatly in the relative development of the accessory "horn," which is sometimes but a mere elevation near the base of the main horn. Individuals with equal and symmetrical horns represent the other extreme. In a few cases tricuspid individuals have been seen, evidencing a tendency to vary towards the type found in *D. varians* Penard and *D. fragosa* Hempel.

This form was about one fourth as abundant as *D. acuminata*, and eight of the ten occurrences fall between May and October, usually with *D. acuminata* and presumably for the same reasons.

*Difflugia constricta* Ehrbg.—Average number, 46. This species occurs irregularly at all seasons of the year without marked preference for the warmer months, and often, but not always, with flood waters. It occurs throughout the whole range of temperatures, and the largest number (2,778 per m.$^3$) appeared during the decline of the spring flood. Data are too infrequent to establish any seasonal routine.

This species varies greatly, and is connected by an unbroken series of variants with the genus *Centropyxis*. Penard ('02) also notes the existence of this connection, and states that after careful search he was unable to find any constant distinction which would suffice for its separation. In my enumeration only the elongated and smooth individuals were referred to this species. The spinose forms were referred to *Centropyxis aculeata*, and those similar in form to the spinose type; but those free from spines, to *C. aculeata* var. *ecornis*.

*Difflugia corona* Wallich.—Average number, 36. In 1896, when the hydrograph was much disturbed, the average number was more than twice as great. This superb species was found in every month of the year except December, but never in large numbers. Its large size (200–300 $\mu$), and its heavy shell militate against its presence in the plankton, and its occurrences are irregular and its numbers few. There is no marked preference for warmer months, and four fifths of its occurrences are in rising flood waters. It is plainly an adventitious planktont. The data are too irregular to trace its seasonal distribution.

As a species it is as well defined as any in the genus. It is not in our waters connected by intermediate forms with other species. Its assignment to *D. lobostoma* by Schewiakoff ('93) is not in my opinion justifiable unless we regard all forms of *Difflugia* as belonging to one species.

*Difflugia fragosa* Hempel.—Average number, 25; in 1896 over 100. This species occurred in every month of the year but February, though three fifths of the records and the majority of the individuals were found between May and October at temperatures above 60°. The data are too irregular to trace the seasonal history of the organism, but they suffice to suggest the agency of floods at all times and of high temperatures during the summer, as factors in the occurrence of the species in the plankton. The shell of this form is relatively to that of other species rather heavy, and this fact combined with the irregularity of its occurrence seems to justify the conclusion that it is largely adventitious at all seasons of the year.

The species exhibits a great deal of variation in the development of the central spine—Hempel ('99, Fig. 1)—and in the number and arrangement of spines in the accessory circlet. The mammillate form of the central spine figured by Hempel is not usually present. Individuals in which the central spine is but feebly developed seem to connect this species with *D. varians*, recently described by Penard ('02). Otherwise, and in our waters, the species is well delimited.

*Difflugia globulosa* Duj.—Average number, 7,194; in 1897, 47,329, the larger number in this year being in part due to a remarkable pulse of 1,240,000 early in September. This is the most abundant of all the rhizopods in our plankton, occurring most frequently and in largest numbers. It is found in every month of the year, and in 1898 appeared in every collection except four in December. With a few exceptions in the autumn of 1898 (Table I.), no large development (exceeding 10,000 per $m.^3$) has taken place earlier than May or later than September—that is, at temperatures below 60°. The occurrences are most continuous and the numbers of individuals are largest during the warmer period between the months named. The largest pulse, that of 1,240,000 on September

7, 1897, was at 80°. A pulse of 48,000 on November 22 at 40° gives evidence of considerable range in adaptation to temperatures.

In Table I. the seasonal distribution of *D. globulosa* is given in full. It differs from that of previous years mainly in the fact that the summer pulses do not here have the amplitude reached in other years; for example, in 1896 (252,000) and 1897 (1,240,000). It is characterized by considerable irregularity caused by somewhat abrupt pulses at irregular intervals. A comparison of these occurrences with the hydrographic conditions (Pt. I., Pl. XII.) indicates that in the colder months increase in numbers in the plankton attends flood waters only, as, for example, in January, February, late October, and November. In the summer, pulses may also come with floods. For example, that of 252,000 on May 25, 1896, appeared on the upward slope of the June rise of the year, and that of 80,000 on June 28, 1897, came with the belated June rise of that year. On the other hand, some of the minor fluctuations appear on declining floods, and the maximum one of our records, that of Sept. 7, 1897, came in the midst of the most prolonged period of stable low water (Pt. I., Pl. XI.) found in the six years of our operations. From these facts it is evident that floods are efficient in increasing the number of *D. globulosa* in the plankton, and that the amplitude of the pulses to which they contribute is much greater in the warmer months (above 60°) than in the colder ones—as a result, perhaps, of the greater numbers present in their normal habitat, the shores and bottom, and also as a result of their readier flotation at this season. In so far as their presence is due to floods they are adventitious. On the other hand, it is very probable that they become temporarily eulimnetic in habit during the summer months. The evidence for this lies in their greater numbers in a period which is predominantly one of greater stability. Thus in 1898, in the 22 collections between May 1 and October 1, the average number present is 9,731, while in the remaining seven months of colder weather the number is only 5,200. Additional evidence arises from the fact that pulses of unusual magnitude have occurred quite independently of any factor such as flood or other disturbance which might cause their adventitious introduction into the plankton. Thus on Sept. 7, 1897, there is a symmetrical pulse whose rise and decline occupy four weeks, as shown in the following table. The total change in river levels in this period of four weeks (Pt. I., Pl.

| Date | Number per m.³ | Turbidity (in meters) | Silt (in cm.³) | Stage of river above low water |
|---|---|---|---|---|
| August 24 | 4,800 | .37 | .15 | 1.8 |
| August 31 | 112,000 | .33 | .19 | 1.8 |
| September 7 | 1,240,000 | .15 | .45 | 1.8 |
| September 14 | 106,000 | .33 | 1.04 | 2.0 |
| September 21 | 800 | .35 | trace | 2.0 |

XI.) was only a fall of .1 and a rise of .2 of a foot—changes due to wind and the operation of the locks in the dams at either end of the pool. The estimated percentage of silt is near the minimum—from a trace to 5 per cent.—and the turbidity was no greater than is customary (Pt. I., Table III.) in our waters during periods of abundant plankton such as this (Pt. I., Pl. XI.). Beyond the presence of these rhizopods there was nothing in the plankton to suggest that the bottom had been stirred up any more than usual. No environmental factor is apparent to which we can attribute this wave of *Difflugia* in the plankton. It is due, I believe, to their own physiological condition. This was a time of prolonged low water and great sewage contamination, and of remarkable development of water-bloom, chlorophyll-bearing flagellates, unicellular algæ, and some diatoms,—all elements in the food of *Difflugia*. In the open water *Difflugia* could find abundant sustenance and thus maintain itself there. It is not strange, then, that we find it in these warm waters, richly charged with its food, assuming for the time a eulimnetic habit, perhaps as a result of rapid growth and lighter shells, and of increased metabolism—with reserve products which lighten the specific gravity and so facilitate flotation.

This species is found throughout the whole range of temperatures. There are indications that its optimum lies above 60°, and perhaps near the maximum, 80°. This may, however, be the result of the effect of temperature upon the food supply of the organism. In any case the plankton data can not suffice to follow the complete seasonal cycle of an organism which is either an adventitious or but a temporary constituent.

The question of specific limits and variation in this organism is one of exceeding difficulty, and I see no satisfactory solution for it until some one attacks the problem by a study of the variation by modern quantitative methods, and endeavors by breeding under control to establish the limits of variation within the normal range of seasonal changes of the environment. When this is done, some more satisfactory criterion for species in this group of planktonts will be feasible than the present condition affords, in which slight differences from previous descriptions are held to be valid for specific distinctions. Thus, in recent years, species of plankton *Difflugia* have been described by Heuscher ('85) (*D. urceolata* var. *helvetica*) from Swiss lakes; by Zacharias ('97) (*D. hydrostatica*) from Lake Plön; by Garbini ('98) (*D. cyclotellina*) from Italian lakes; by Levander ('00) (*D. lobostoma* var. *limnetica*) from Finnish waters; and by Minkiewitsch ('98) (*D. planktonica*) from Russian waters. All of these forms occur in the Illinois River, and there are others equally worthy of specific designation in our plankton as yet undescribed. They occur most abundantly at the times of the pulses, especially of those in stable conditions. In my opinion they are all mere limnetic varieties of *D. globulosa* or *D. lobostoma*, the form of the shell and its constituent particles being modified by the habit of life in which these individuals of the seasonal cycle are found. They occur at times of abundant food, rapid multiplication, and limnetic environment. Their shells are accordingly lighter, more chitinous and transparent, and the foreign particles adherent to them partake of the nature of those of the silt in suspension. This, however, is merely an opinion based upon an examination of the statistics of occurrences, and upon the work of plankton enumeration in which all individuals must be assigned to some species. This is at least a different point of view from that of the systematist, who may, perhaps, lay more stress upon divergences from described types and less upon links connecting such variants. For the sake of genuine progress in the science it would seem to the writer extremely desirable that more attention be given to the question of variation and less to the description of new species under criteria now in vogue. It may be desirable, indeed necessary, to distinguish such forms in the plankton. It would be both safe and conservative to designate them as forms, or, at the most, as varieties.

The location of the pulses of *D. globulosa* bears no constant relation to those of other organisms, owing, in part, at least, to the irregularities of the floods upon which some of them seem to depend. The great pulse of Sept. 7, 1897, is intercalated between two pulses of diatoms and other chlorophyll-bearing organisms, and some others bear a similar relation to their food supply, while some coincide with an increase in these synthetic organisms (cf. Table I. and Pl. II.).

*Difflugia globulosa* and the following species were reported by Smith ('94) in the plankton of Lake St. Clair; by Jennings ('00a) in that of Lake Erie; and were common in the plankton of Lake Michigan (Kofoid '95). *Difflugia* of the forms included here under *D. globulosa* and *D. lobostoma* have been reported by many authors from various European lakes and rivers, but in no reported instance do they reach the numbers or importance in the plankton that they do in the Illinois. Full records of their seasonal distribution may, however, bring such importance to light.

*Difflugia lobostoma* Leidy.—Average number, 1,158. In the total of all collections it is about one fifth as abundant as *D. globulosa.* Like that species it occurs throughout the whole year in almost every collection (Table I.), and the fluctuations in its occurrence follow very closely those just described for *D. globulosa* in the direction of their movement. The amplitude of the pulses is less, as a rule, and their culminations and limits are coincident, or at least approximate. Thus, on Sept. 7, 1897, *D. lobostoma* attains only 24,000, and the pulse of *D. globulosa* on June 28 (80,000) is attended by one of 96,000 in *D. lobostoma* in the next collection, on July 14. There are in this species also the same influx into the plankton with floods, and increase in numbers at temperatures above 60°. There are 954 per collection per cubic meter below this temperature to 1,436 during the warmer months in 1898. There are also pulses during the warmer months, in stable conditions, coincident with those of *D. globulosa.* Similar causes presumably contribute to these results in both species.

*Difflugia lobostoma* is also exceedingly variable in proportions, in the texture of the shell and the degree of incision, and in the number of lobes about the mouth. Two, three, and even four have been noted, and they vary greatly in depth, in regularity, in perfection of their development, and in the structural border which sometimes forms their margin. Chitinous, brownish, or more or less transparent shells are abundant when pulses occur. Forms which connect this species with *D. globulosa* have been observed. Included with *D. lobostoma* are forms which have since been described by Penard ('02) as *D. gramen*, *D. gramen* var. *achlora*, and *D. lithoplites*, though I have not found in the Illinois plankton any of the last-named with the peculiar tipped horns found by Penard upon many individuals of his species.

*Difflugia pristis* Penard (?).—A small *Difflugia* was found occasionally in the filter-paper collections in the colder months, but only from November to March. It was often dark, or even blackish, resembling in this respect Penard's *D. pristis*. Individuals not thus darkened approach more nearly *D. fallax* Penard and *D. pulex* Penard.

*Difflugia pyriformis* Perty.—Average number, 368. This species occurred in every month except January, but generally in small numbers and irregularly. The largest number taken—12,000, on May 25, 1896—came with the flood at that time (Pt. I., Pl. X.), and all the large occurrences of 1898 came with rapidly rising water (cf. Table I. and Pt. I., Pl. XII.). There are no indications of pulses during stable conditions, and we must conclude that the species is purely adventitious in our plankton. It is one of the largest species with a heavy shell, and its flotation is impeded thereby.

This species is exceedingly variable. The following varieties or variants, given specific rank by some writers, have been noted, and are included with *D. pyriformis* in the enumeration: *D. pyriformis* var. *nodosa* Leidy, *D. pyriformis* var. *claviformis* Penard, *D. pyriformis* var. *venusta* Penard, and *D. pyriformis* var. *lacustris* Penard. A more slender and smoothly contoured form than the last is not uncommon.

*D. capreolata* Penard and *D. bacillifera* Penard were also found, but are rare.

*Difflugia rubescens* Penard was taken but once—on May 25, 1896.

*Difflugia tuberculosa* Hempel was also found but once in the planktons enumerated, though Hempel ('99) reports it as appearing occasionally from August to November in 1895.

*Difflugia urceolata* Carter was taken only in April and May, 1896, in small numbers at temperatures of 66°–80°.

*Dinamœba mirabilis* Leidy was found in the plankton but once—Apr. 12, 1898, in small numbers, at 52°.

*Euglypha alveolata* Duj. was found in small numbers in the plankton, but only on Nov. 1, 1898, and March 14, 1899, at temperatures of 45° and 36°.

*Euglypha ciliata* Ehrbg. appeared in the filter-paper collections in 1897, in July, August, and November, in small numbers at temperatures ranging from 80° to 48°. This is said by Penard ('02) to be predominantly a sphagnum species, but widely distributed elsewhere in small numbers.

*Euglypha lævis* Perty.—This minute rhizopod was found in the filter-paper collection of Oct. 4, 1898, at 72°.

*Nebela collaris* Leidy was found only once—on June 25, 1898, at 32°.

*Pontigulasia incisa* Rhumbler.—This curious rhizopod occurred in the plankton in July and August, 1895, and again in August and September, 1897, at temperatures of 75°–85°. Both occurrences were in stable conditions, and the temporary adoption of the limnetic habit is suggested by their appearance at these times. Two other records in 1897—on March 22 and November 9, at 44° and 50°— extend the seasonal range of the species. These occurrences attended rising water and were apparently adventitious.

*Trinema enchelys* (Ehrbg.) Leidy.—Average number, 158. This little cosmopolite rhizopod of the sphagnum fauna was found but eight times in the plankton. The individuals observed were all darkened by the granular food vacuoles to such a degree that structural details were obscured. It was noted only in the somewhat turbulent years of 1898 and 1899, though on account of its small size and the obscurity of its structure it may have been overlooked in previous collections. The few occurrences are insufficient to establish any seasonal routine. They were at both extremes of the temperature range and in all seasons but spring, with a predominance in late summer and fall. The species is evidently adventitious in the plankton, as shown by irregular distribution and small numbers, and by the fact that its occurrences coincide in all instances but one with rising water.

## HELIOZOA.

The *Heliozoa* of the plankton of the Illinois are few both in number of species and of individuals. They apparently play but a small part in the economy of the plankton. The average number for 1898 was but 4,883. Their occurrences are confined in the main to midsummer and early autumn. But four species were identified, though several others remain undetermined for lack of sufficient material, especially of the living forms. Apstein ('96) reports *Heliozoa* in considerable numbers in German lakes, with maxima in July–August. It is probable that these delicate forms are frequently crushed in manipulation or hidden in silt in our collections.

### DISCUSSION OF SPECIES OF HELIOZOA.

*Actinophrys sol* Ehrbg.—Average number, 62. This species occurred irregularly from April to the early part of November at temperatures above 46°. It was recorded most frequently in the latter part of the summer, the largest number (28,000) appearing Sept. 7, 1897, at 80°.

*Actinosphærium eichhornii* (Ehrbg.) Stein.—Recorded a few times, from July to October, at maximum temperatures (75°–80°), but always in small numbers.

*Endophrys rotatoriorum* Przesm.—This heliozoan (?) has been recently described by Przesmycki ('01) as parasitic, during a part of its existence, in *Philodina* and *Hydatina*. A parasite resembling this parasitic stage of *Endophrys* was observed by me in a bdelloid rotifer (*Rotifer tardus*) on several occasions, but it was never abundant, nor was its connection with any free-swimming condition noted. The heliozoan affinities of this organism seem very questionable.

*Nuclearia delicatula* Cienk.—Average number, 4,760. This species in 1898 appeared first on June 21, attained a pulse of 78,400 on August 9 at 82° and another abrupt one of 65,600 on September 27 at 73°, and made its last appearance October 25 at 48°. Occurrences in previous years are confined to midsummer. Its optimum conditions of temperature obviously lie near the summer maximum, and its lower limits near 50°. Its appearance in the plankton is not traceable to flood conditions, and it is apparently eulimnetic in our waters.

Hempel ('99) reports *Raphidiophrys pallida* Ehrbg. and *R. elegans* Hertwig and Less. in the plankton of Quiver Lake adjoining the river, and I have found an undetermined species of *Acanthocystis* and a small heliozoan resembling *Nuclearia* in the river plankton.

## SPOROZOA.

*Triactinomyxon* sp.—In the plankton collections of each year there have been found free limnetic spores which unquestionably belong to that highly aberrant and peculiar group of organisms described by Stolč ('99) as *Actinomyxidia* and regarded by him as *Mesozoa*, but later referred by Mrazek ('00) Caullery and Mesnil ('04), and Leger ('04) to the *Myxosporidia*. The organisms described by Stolč were parasitic in fresh-water oligochætes, and it is not improbable that the limnetic spores taken in our plankton collections are derived from parasites in some of the numerous aquatic oligochætes, or other invertebrates, found along the bottom and shores of the stream.

The species here referred to *Triactinomyxon* differs in some details from *T. ignotum* Stolč. It was found in the course of the six years at least once in every month of the year, but most regularly in May–September, and rarely and in small numbers in the colder months. Its transparency and long, slender, radiating, tripod-like arms give it a typically limnetic habit.

*Actinomyxidia*, gen. et sp. indet.—Clusters of eight, or less, cylindrical spores radiating from a common center and bearing a marked resemblance in structural features to those of *Triactinomyxon*, but lacking any anchor-like projections, were found sparingly in the plankton in June–September.

The distinctively limnetic habit of these spore stages in the life-history of these parasites is unique among the *Sporozoa*, and has not, to my knowledge, been before noted.

Many of the rotifers of the summer plankton, especially *Brachionus* and an occasional *Asplanchna*, have been heavily parasitized internally by small sac-like bodies, often pear-shaped, with the smaller end attached to the lorica, or of spherical or flattened form. They occur in such numbers at times as to be a menace to the rotifer population. They are usually most abundant in any given species at the time of, or subsequent to, its maximum occurrence. It was not unusual to find as high as ten or fifteen per cent. of the individuals parasitized, and a number of empty loricæ bearing additional testimony to their destructive agency.

Bertram ('92) describes these structures as "parasitische Schläuche" in the body cavity of rotifers, and Przesmycki ('01) works out their life history, and describes the organisms as *Dimœrium hyalinum*, but does not designate their systematic position or affinities. There are, however, marked suggestions of sporozoan affinities in the organism found in the rotifers of the Illinois plankton, which seems to be identical with that described by Przesmycki ('01).

Obviously it is difficult to take a census of such internal parasites. A record was kept, however, of the number of parasitized individuals in each species of rotifer, and references will be made to these results in the discussion of the hosts. *Dimœrium* appeared in both summer and winter rotifers, and its seasonal distribution naturally depends upon the number of available hosts. It was in consequence most abundant during the midsummer and autumn months.

### CILIATA.

Average number, 15,812,346, including filter-paper collections. If these be excluded and the silk catches only averaged, the number will fall to less than a tenth of this sum. The ciliates are found in the plankton of the Illinois throughout the whole year, and as a whole they do not exhibit any common seasonal predominance. The analysis of the distribution of the individual species which follows, exhibits two diverse tendencies which affect the distribution of the totals. These are the vernal and autumnal pulses of the *Tintinnidæ*, represented by *Codonella cratera* and *Tintinnidium fluviatile*, and the autumnal-winter occurrence of a large number of species during the height of the sewage contamination and bacterial development. The dominant species in this ciliate wave are *Carchesium lachmanni*, *Epistylis*, *Amphileptus*, *Lionotus*, *Plagiopyla nasuta*, *Glaucoma scintillans*, *Stentor niger*, and *S. cæruleus*. Some species, as *Halteria grandinella*, have a wider seasonal distribution, and others, as *Vorticella*, *Trichodina*, *Zoöthamnium*, *Pyxicola affinis*, and many others, are adventitious in the plankton. Still others, as *Rhabdostyla*, *Cothurniopsis vaga*, *Opercularia*, and similar peritrichan parasites, are passive members of the plankton. The actively limnetic ciliates are very few. As such we may include *Codonella cratera*, *Tintinnidium fluviatile*, and possibly *Stentor niger*. *Carchesium lachmanni* and *Epistylis* enter the plankton only in the form of detached and often moribund zoöids, and thus are not typical planktonts, though of quantitative importance in our plankton in the colder months. A large number of species not here reported occur in our collections made elsewhere than in the river channel, especially in places where the decay of large quantities of organic matter is in progress. This is not a condition normally found in the open water of lakes, though it may occur along their shores, where vegetation is found, or in regions of sewage contamination. In the waters of the Illinois, on the other hand, the current, combined with sewage and industrial wastes and the organic detritus from the richest of fertile prairies, provides a suitable environment, even in the open water, for the support of a ciliate fauna of a magnitude somewhat unusual in fresh-water plankton. This fauna is present also in the backwaters, but is less abundant there than in the river itself. These species occur in greatest numbers of individuals in our plankton during the winter months at minimum temperatures, rising in November as the temperature falls below 50°, and declining again as it rises to this point in April. As shown by the bacteriological investigations of Jordan ('00) and Burrill ('02 and '04), the bacterial pulse attending the decay of the sewage and wastes at Peoria does not reach Havana during the warmer months (see table on p. 231, Pt. I.), but when temperatures pass below 50° in November the increase in bacteria is marked. The decay is less rapid at low temperatures, and the process is still going on when the water in the channel passes Havana during the prevalence of low temperatures, and the ciliates that thrive in such an environment abound in the plankton at that time.

The temperature limits of these ciliates of the period of bacterial development thus seem to lie between 50° and 32°. An examination of the plankton in the river at several points between Peoria and Havana at intervals throughout a year, will reveal how far the component species of this ciliate fauna are governed in their seasonal distribution in the plankton at Havana, respectively, by conditions of temperature and by the state of sewage contamination. The work of Roux ('01) upon the *Ciliata* about Geneva would seem to indicate that many species of the fauna of stagnant water are more abundant in that region during the winter months. Owing to the difference in food conditions attendant upon the increase of sewage and bacteria during the colder months in the Illinois River, it is impossible to determine from the data at hand the relative efficiency of the two elements of temperature and food in regulating the seasonal occurrences of our ciliates.

Here, as elsewhere, the disastrous effect of sudden floods can be traced. The number of ciliates (Table I.) drops as floods rise, and recovers as the waters fall again. For this reason the winter occurrences of the total ciliates are subject to considerable disturbances in the winter floods of the several years. The combination of the two methods of collection and of the two groups of ciliates, typical and adventitious, causes further irregularities (Table I.) in the seasonal distribution of totals.

In the Illinois River, for reasons given above, the *Ciliata* occupy a place in the economy of the plankton of more than the usual importance. They feed principally upon bacteria, decaying organic matter, and the smaller algæ, and are themselves eaten by the rotifers. I have found no evidence that they are utilized by the *Entomostraca*. They thus become active agents in the reduction of sewage and in the destruction of the bacteria of decay, in the purification of sewage-laden waters, and in the transfer of the matter in sewage to higher forms of animal life.

The ciliates found in the Illinois include all the important species reported in the plankton of fresh water, and the list is somewhat larger than hitherto recorded in quantitative plankton collections in river or lake waters. These organisms escape readily through the silk net by reason of their small size, and in some instances the larger species, by reason of their mobility and flexibility, escape through the silk where less motile organisms of equal size are retained. By experiment I have found that well-shrunken silk bolting-cloth whose meshes average about 30–45 $\mu$ will not retain *Paramecium* whose diameter is 40–70 $\mu$. It may be that supplementary methods of collection which will correct the error of leakage will show that the *Ciliata* are of wider occurrence in the plankton than has hitherto been found to be the case.

DISCUSSION OF SPECIES OF CILIATA.

*Amphileptus* spp.—Average number, 630. *Amphileptus* is a well-defined winter planktont in the river at Havana, and it affords a striking instance of the interdependency of organisms in the plankton. It feeds upon the heads of *Carchesium lachmanni*, engulfing the head *in situ* and encysting during digestion. Such heads, joined to the colony or free in the plankton, have been found in our waters. Its seasonal distribution at Havana is almost identical (Table I.) with that of *Carchesium*, upon which it feeds. Thus in 1897–98 *Carchesium* was continuously present in the plankton from October 26 to May 10, with a pulse on December 7 of 283,800, and one on February 8 of 197,600. *Amphileptus* appears October 26; continues, with interruptions, to May 17; and has pulses December 7 and January 25, the latter reaching 13,545. In 1898–99 both appear early in October and have coincident pulses on November 22 and January 24. In 1895–96 the interdependence is even more striking, *Carchesium* reaching a greater development in this winter, with a pulse of 964,600 on November 27, and *Amphileptus* reaching 14,469 on this date and 14,835 a week later. Both species decline during the flood which follows, and rise during March to culminations, on the 24th, of 104,535 and 3,636, respectively.

In 1898, *Amphileptus* disappears on April 12 at 52°, save for an isolated occurrence May 17 at 64°. It does not reappear until October 18 at 52°. In 1897, it reappeared October 26 at 59°, and in 1895–96 its limits were 45° and 48°, with the exception of one occurrence, April 17, at 66°. *Carchesium* occurs irregularly and sparingly during summer months, and *Amphileptus* was not taken in the plankton during that period. Its occurrence in the plankton is limited in the main to temperatures below 50°, but this limitation may be due primarily to the reduced numbers, at higher temperatures, of the organism upon which it feeds. It appears during the period of greatest sewage-contamination and bacterial development in the river at Havana. Roux ('01) finds *Amphileptus* most abundant in stagnant waters about Geneva in the winter months.

*Aspidisca costata* (Duj.) Stein.—Found in the plankton but once —Jan. 11, 1898, at 32°.

*Bursaria truncatella* O. F. Müll.—Average number, 23. This large ciliate was found in the plankton at irregular intervals and in small numbers. It was found six times in March; twice in January and April; and once in February, July, and November. Its appearance in the plankton is thus predominantly in winter months and at temperatures below 45°, though it occurs in the extremes of temperature conditions.

*Carchesium lachmanni* S. Kent.—Average number, 26,546. This is normally an attached species, and its appearance in the plankton is due to the detachment of the heads. Small fragments of colonies are also found, but the greater number are isolated heads. The detachment seems to be a physiological process of the organism and not merely the result of accidents. It is thus a detached and an adventitious planktont. Many of the heads taken in the plankton are in a moribund condition. For example, in a pulse of March, 1896, the following proportions were recorded.

| Date | Total *Carchesium* per m.$^3$ | Per cent. normal | Per cent. moribund |
|---|---|---|---|
| 1896 | | | |
| March 17 | 60,420 | 55 | 45 |
| " 24 | 104,535 | 48 | 52 |
| " 30 | 47,571 | 53 | 47 |
| April 10 | 16,688 | 39 | 61 |

Enumerations were based on the total number of heads, both normal and moribund. The colonies are sessile, and adhere in vast numbers to any substratum furnishing a suitable place for attachment—submerged vegetation, brush, sticks, and fishermen's nets. The latter sometimes become so clogged with *Carchesium* and floating mats of *Crenothrix* and *Beggiatoa* as to break down in the current of the river. How far the number of free heads in the plankton is an index of the development of the species in the stream can not be determined from the data at hand.

This species has been taken in the plankton in every month of the year, but its occurrences between the early part of May and

October 1—that is, above 60°— are irregular and the numbers few (Table I.). It is thus predominantly a cold-water planktont. Winter collections in 1894–95 and 1896–97 were too few to trace its seasonal movements. In 1896–97 it appeared November 5, rose to a maximum of 964,600 on November 27, and declined in the December–January flood (Pt. I., Pl. IX.) almost to extinction, but recovered during its decline to a minor pulse of 16,160 on January 30. It again fell off in numbers during the floods of February (Pt. I., Pl. X.), but rose during the decline of March to a maximum of 104,535 on March 17. Numbers become smaller and occurrences irregular after May 1.

In 1897, *Carchesium* increased rapidly in late October to a small pulse of 13,200 on November 2, with a decline in the following fortnight, and a pulse culminating December 7 at 283,800, with subsequent decline. The fluctuations during 1898 may be followed in Table I. The numbers increase during the slowly rising flood of January to a maximum of 197,600 on February 8 at 32°, and decline again during the more rapid rise (Pt. I., Pl. XII.) of the next three weeks. Stable conditions in early March bring about a pulse of 89,600 on March 15, and numbers decline again to 2,400 as the flood passes its maximum in the early part of April. As the levels fall another pulse of 99,200 appears April 26, from which a descent to minimum numbers—which prevail during the summer—takes place within a fortnight. The floods, especially sudden ones, seem thus to interfere with the appearance of *Carchesium* in the plankton, while gradual rises, as that of November, 1898, are not so detrimental.

The table of bacterial occurrences (Jordan, '00) in the Illinois at Havana and Pekin given on p. 231, Part I., indicates that the bacterial development consequent upon the sewage and industrial wastes of Peoria extends down the river to Havana during the colder months of the year. The occurrence of *Carchesium* in the plankton is thus coincident with that of greatest sewage pollution and bacterial development at Havana. *Carchesium* is much more abundant in the channel of the river, where sewage pollution is greatest, than it is in the adjacent backwaters. It seems probable that the bacteria either directly or indirectly contribute towards its development, constituting, it may be, an important element in its food. Flood waters, which dilute the sewage (cf. hydrograph and chlorine in Pl. XLV. of Part I.) might for this reason tend to interfere with the development of *Carchesium*, and thus cut off the source from which the plankton individuals arise. I am not able, however, to trace any close correlation between the fluctuations of the chemical matters indicative of sewage and sewage decay and those of *Carchesium*. In the stable hydrographic conditions of 1897 we find a symmetrical pulse of considerable dimensions rising from 2,200 on November 9 to 283,800 on December 7, and declining to 26,500 on January 11, 1898. Stable low water with an ice blockade (Pt. I., Pl. XI. and XII.) characterize this season. No explanation for the fluctuation is suggested in the physical environment. The chemical condition of the water, was, however, greatly disturbed (Pt. I., Pl. XLIV.). The fivefold increase in free ammonia is indicative of approaching stagnation under the ice, and the threefold increase in chlorine marks the sewage concentration. Approaching stagnation might have caused the decline of *Carchesium*, or it may be a specific reproductive cycle of the organism which combines with the external factors of the environment to produce such a wave of occurrence.

*Chilodon cucullulus* Ehrbg.—Average number, 102. This species was found in the plankton in January and February during the bacterial increase. It was also found in July. It escapes through the silk net, and does not ordinarily appear in plankton collections, though abundant wherever decay is active.

*Codonella cratera* (Leidy).—Average number, 101,024 or 452,500*. This is the most abundant of the ciliates in our plankton, constituting about one third of their total number. It appears in every month of the year, and in 1898 it was recorded in every collection but one, that of December 13 (Table I.). It is subject to great fluctuations in numbers, its maximum occurrences tending to appear in April, May, or June, and again in September or October. Minimum numbers prevail during the winter, when many of the shells are empty, and the midsummer interval is subject to pulses of varying amplitude. Spring pulses were detected as follows: in 1895, on April 29 (16,324) at 64°; in 1896, on April 24 (562,152) at 72°; in 1897, on April 27 (470,000) at 60°; and in 1898, on May 3 (736,000) at 60°. These vernal pulses coincide with or approximate closely to the dates of the spring volumetric pulses. This somewhat remarkable approximation of dates near the end of April may be the result, in part at least, of the dates of collection; but after allowance is made for this, the species still exhibits a seasonal cycle of remarkable regularity. The autumnal pulse is of less amplitude, and of less regularity in location as to time and temperature. In 1894 it appears September 4 (14,000) at 78°; in 1895, on September 12 (5,840) at 81°; in 1896, on August 29 (58,800) at 74° or October 14 (63,200) at 57°; in 1897, on October 5 (204,400) at 71°; and in 1898, on September 27 (92,800) at 73°.

The midsummer pulses are, as a rule (Table I.), of less amplitude than the vernal or autumnal ones. In 1896 and 1898 exceptions to this statement appear in two large developments which follow in each case upon the decline of the June rise. In 1896 (Pt. I., Pl. X.) this pulse (152,400) came June 11, and in 1898 (Pt. I., Pl. XII.) it came (1,499,200) June 7 at 78° and exceeded in amplitude the recorded vernal pulse. In both cases the pulse was recorded as occurring at an interval of a week after the crest of the June rise had passed. The character and sequence of these pulses is well shown in Table I.

The occurrence of *Codonella* in abundance in the purer backwaters and in the plankton of our Great Lakes (Kofoid, '95) indicates that it is not dependent upon the sewage bacteria directly for food for its development in our waters. The appearance of the greatest pulses during a period of considerable sewage dilution still further indicates its independence of sewage bacteria. A comparison of the fluctuations of the totals of the chlorophyll-bearing organisms with those of *Codonella* affords some evidence of a correlation between the two. Of 39 pulses which can be traced in our records in the chlorophyll-bearing organisms, 21 precede and 13 coincide with those of *Codonella*, while in the remaining 5 instances the multiplication of *Codonella* precedes that of the phytoplankton as a whole. Thus in the main the pulses of *Codonella* follow, or coincide with, those of the phytoplankton. The evidence of this sequence may be followed in Table I. by a comparison of the records of *Codonella* with those of the total phytoplankton. The sequence indicates that the food of *Codonella* may be found in the phytoplankton, and that these recurrent periods of growth have some connection with the conditions of nutrition. The seasonal cycle of *Codonella* is closely followed by the other member of the family found in our plankton—*Tintinnidium fluviatile*.

*Codonella* occurs throughout the whole range of temperatures. The winter minimum and the decline during the maximum temperatures of summer, combined with the presence of vernal and autumnal, or late summer, pulses, indicate that the optimum conditions for this organism lie neither in winter nor in summer. The spring pulse was at temperatures of 60°–72°, and the autumnal one at a wider range of 57°–78°. Permanent increase in numbers does not begin (Table I.) until March 15 at 46°, and the permanent falling off is found on November 15 at 41°. The optimum temperatures in our waters thus lie near 60°–70°, and conditions favoring growth are limited to a range of 10°–15° upon either side of the optimum.

This species readily escapes through the silk net on account of its small size and its motility, and such collections give at the best incomplete evidence of its seasonal distribution. The amplitude of its fluctuations is thus reduced, and owing to the irregularity of the error arising from leakage, the reduction is not proportionally distributed throughout the year. Tests made of the loss of *Codonella* by leakage through the silk indicated that but one was retained to twenty-four found in the filtrate. *Codonella* was counted in both the silk and filter-paper collections, with the result that in 1897 the totals for the year (omitting one date on which the filter collection contained an unusually large number of *Codonella*) showed one *Codonella* in the silk to twenty-five in the filter collection. In 1898, however, the ratio was one to four and a half. The error in the filter collection is large, but data seem to justify the conclusion that only a small proportion of the *Codonella* is retained within the silk net. The proportion for the whole period of collection by the two methods (August 3, '97, to March 28, '99) is one to seven, if one date on which aberrantly large numbers appear in the filter collections be omitted.

This species is a typical planktont, and is apparently the same as *C. lacustris* Entz, by which name it is designated by European writers. Leidy's name, however, has priority according to the accepted rules of nomenclature. It is an exceedingly variable organism, at least in the form, proportions, and size of the shell, in the degree of its constriction, and in the foreign particles which fill its matrix. The rings or bands which ornament the orifice vary in their number, width, and relative proportions, and in the perfection of their development. The intergradation which these variants exhibit is sufficient to my mind to make their elevation to specific rank unjustifiable.

*Codonella* is an important element in the food of many of the limnetic rotifers, especially *Asplanchna*.

*Codonella* is a common constituent in the plankton of our own Great Lakes (Smith, '94; Kofoid, '95; Jennings, '00a), and has been reported from most European waters. Apstein ('96) finds in German lakes major pulses in spring and autumn and minor ones in midsummer. Lauterborn ('94) reports *Codonella* in the plankton of the Rhine, and Schorler ('00) in that of the Elbe, but neither follows its seasonal history.

*Coleps hirtus* Ehrbg.—Average number, 13. This species occurred in the plankton collections irregularly and in small numbers, principally in autumn months during the height of the bacterial development. It escapes through the silk readily.

*Colpoda cucullus* Ehrbg*.—Average number, 9,615. This species appears in the plankton principally during the colder months of bacterial predominance, from November to April, and occasionally during the summer.

*Cothurniopsis vaga* (Schrk.) Blochmann was found in both 1898 and 1899 on *Canthocamptus*.

*Didinium nasutum* (O. F. Müll.) Stein*.—Average number, 12,692. This species also is found in the plankton during winter months, especially in November and December during the bacterial increase. It was also found in midsummer.

*Epistylis* spp.—Average number, 2,020. The free heads or fragments of colonies of one, or possibly of several, unidentified species of *Epistylis*, or it may be of *Opercularia* also, were associated with *Carchesium lachmanni* in the plankton during the colder months, but in much smaller numbers (1 to 13 in 1898). Identification in most cases was impracticable, though in some instances *E. flavicans* Ehrbg. was determined, and it seems probable that most of the winter forms at least belong to this species. Hempel ('99) reports *E. plicatilis* on snails, and various other aquatic animals have been found infested with colonies of undetermined species of *Epistylis*.

The distribution of *Epistylis* in the plankton (Table I.) is in its limits somewhat like that of *Carchesium*. It is more abundant and more continuously present during the period from November to June (at temperatures below 60°) than in the intervening warmer months. It is found throughout the whole range of temperatures. Its pulses coincide with those of *Carchesium* when they occur, but they are not always found in *Epistylis* when they appear in *Carchesium*. This degree of similarity in the seasonal cycle of the two genera is indicative of their correlation with the same environmental factors, the principal one of which is the increase in bacteria attending the colder months.

*Euplotes charon* (O. F. Müll.) Ehrbg. was taken but once in the plankton—August 23, 1898.

*Euplotes patella* Ehrbg*.—Average number, 2,888. It was found in small numbers and at irregular intervals from April to December throughout the full range of temperatures. It was most frequently taken in the summer.

*Glaucoma scintillans* Ehrbg.*—Average number, 39,615. This species was taken in the plankton from the middle of October till the middle of April. It was present in larger numbers and more continuously in December and February. It is thus a member of the plankton during the time of bacterial increase.

*Halteria grandinella* O. F. Müll.*—Average number, 255,769. The seasonal distribution of this species in the plankton does not show the limitation to the winter months noted so frequently in other ciliates. It was found in every month of the year but May, in largest numbers in July and August, and most continuously in December and January. The data are too few and irregular to determine any predominance as to season or temperature.

*Holophrya simplex* Schew. was found in small numbers in the filter collections of December, February, and March in the winter of 1896–97 at temperatures from 32° to 44°.

*Leucophrydium putrinum* Roux.—Average number, 525. This species was recorded July–September, 1898, during the low-water period, at temperatures from 89° to 63°. It was described by Roux ('99) from stagnant water, but in our plankton no conditions of stagnation attend its presence, though sewage contamination is great and decaying organic matter abundant.

*Lionotus* spp.—Average number, 94. With *Amphileptus* in the winter plankton there occur a number of other, smaller, gymnostome ciliates which in best-preserved specimens resemble *Lionotus*. A few occurring in March and April, 1898, were found to be *L. fasciola* Ehrbg., and it is probable that most of the individuals belong to this species, though exact identification is difficult with plankton material. The seasonal distribution of *Lionotus* coincides very closely with that of *Amphileptus.* The species appear in November or December and continue through March in temperatures below 50°, but the numbers retained by the silk net are too small to trace their seasonal routine. Their seasonal distribution in the plankton coincides with the period of greatest access of sewage and bacterial increase in the river at Havana. Roux ('01) finds this genus well represented in the fauna of swamps, and most abundant in October and March.

*Loxodes rostrum* Ehrbg. was identified but once—March 22, 1897, at 44°.

*Nassula rubens* Perty occurred July 30, 1897, at 84°.

*Opercularia articulata* Goldf.—This species is parasitic upon aquatic *Coleoptera.* In the plankton of June 28, 1897, eleven colonies or fragments of a colony were found, the largest with 115 zoöids.

*Opercularia nutans* (Ehrbg.).—Average number of zoöids, 60. In the plankton this species was found attached to *Alona affinis* in January, 1898, and to *Cyclops* in April and August.

*Opercularia* not specifically determined were found free in the plankton in June and July; in November, attached to *Canthocamptus*; in January, attached to *Brachionus*—and even to the eggs of this species. An unidentified form was also found upon *Cyclops.*

*Ophryoglena atra* Lieberk.—Five irregular occurrences of this species in small numbers were recorded in 1899 from January to the middle of March.

*Paramecium* spp.—Average number, 41. *Paramecium* was found 18 times in the plankton. Two of these instances were in May and August at temperatures of 64° and 79°, and the remainder were between November 20 and March 30 at temperatures below 48°. Most of the occurrences are in midwinter at minimum temperatures under the ice. *P. aurelia* (O. F. Müll.) has been found in the river waters (Hempel, '99), but not all taken in the plankton belong to this species. Specific determinations are not easily made with accuracy in preserved plankton material. In our plankton, *Paramecium* is present principally during the period of greatest contamination by sewage.

*Plagiopyla nasuta* Stein*.—Average number, 1,181,000 during the winter of 1898–99 from November 29 to March 28. This species was not recognized in the plankton of previous winters. It reaches a pulse of 11,520,000 on January 3, 1899, at 32.2° under the ice.

Levander ('94) finds it in numbers under the ice in Finnish waters. On account of its motility and small size it readily escapes through the silk net.

*Pleuronema chrysalis* (Ehrbg.) Stein.—Average number, 9. Recorded only in January, 1898, at minimum temperatures.

*Prorodon farctus* Clap. and Lach.—Only a few scattered occurrences—from the last of September to the first of March at temperatures from 73° to minimum. An unidentified species of *Prorodon* was also found irregularly from November to April.

*Pyxicola affinis* S. Kent.—Average number, 58. This species is usually attached to aquatic plants, especially to *Lemna*. It has been found in the summer plankton from June to August during maximum temperatures, especially in 1896, when recurrent floods brought much *Lemna* from the backwaters into the river. It was found October 18 at 52°, attached to *Melosira varians*.

*Rhabdostyla* spp.—Average number, 110. Peritrichan ciliates referred to this genus have been noted on *Cyclops*, *Canthocamptus*, *Oligochæta*, and even in considerable numbers upon the body, appendages, and eggs of *Polyarthra platyptera*. They have appeared thus passively in the plankton during winter months from December to March, especially in 1899.

*Stentor cæruleus* Ehrbg.—Average number, 882. This species presents a characteristic seasonal distribution in our plankton. Its numbers are never very large, and its full cycle can not always be traced in the records. It is a planktont of the colder season in our waters. But three records—one July 28, 1896, at 82°, one August 3 of the same year at 80°, and a third, August 15, 1894, at 84°—lie outside of the period between September 1 and May 1. In 1898 (Table I.) the autumn cycle begins September 6 at 79°, but in both 1895 and 1897 the species does not appear until late in November or in December at 34° or below. In years prior to 1898 the numbers were small and irregular, but on January 21, 1898, the maximum number of 28,800 was reached at 34°, under the ice, during the slowly rising flood of that month (Pt. I., Pl. XII.). It accompanied an increase in *Stentor niger*, and there are indications elsewhere that the two species may fluctuate together. The high (Pt. I., Pl. XLV.) chlorine (38.), nitrites (.175), and free ammonia (4.6) at the season of greatest development in the plankton are indicative of conditions approaching stagnation. The appearance of this species in stagnant water has often been observed. Roux ('01) finds it especially abundant in September, October, and February in stagnant waters about Geneva.

*Stentor niger* Ehrbg.—Average number, 3,124. In our waters this species also is a winter planktont (Table I.). There have been but four records of occurrence between May 1 and September 1. In 1895–96 the species appeared November 14 at 44° and reached a maximum of 68,635 December 18, after three weeks of minimum temperatures and approaching stagnation under the ice. Numbers declined in the December–January flood (Pt. I., Pl. X.), but rose again in March, as the flood declined, to 39,087 on the 24th at 40°. It disappeared from the plankton April 30 at 70° and did not reappear until November 17, from which time it continued until March 22. In 1897–98 it returned September 21 at 71°, attained a maximum of 42,000 November 23 at 43°, declined during December, and rose to 47,000 on January 21 at 34° under the ice, and in the conditions approaching stagnation described in connection with the discussion of *S. cæruleus*. A decline in numbers continued until April 12 at 52°. Favorable conditions for growth are thus found in our waters between 32° and 50°, and the optimum seems to lie near 40° or below.

This species reaches its greatest development in our waters during the time of greatest sewage pollution and bacterial development. It is known as a bog-water species, and was found by Roux ('01) in stagnant waters about Geneva during the colder months. Hempel ('99) reports this species as *S. igneus* (?), but from the descriptions of Roux ('01) I am inclined to consider it as *S. niger* Ehrbg. It may be that both species are included in our data, but they are predominantly of the *niger* type. They include also individuals of the blackish variety *S. igneus* var. *fuliginosus* Forbes, which, it would seem from Roux's description of these species, should be transferred to *S. niger*. The *fuliginosus* form was very abundant in the margins of Pine and Round lakes, Michigan (Kofoid, '95), during the summer in surface temperatures of 61°–70°, where sewage contamination was but slight.

*Stentor polymorphus* (O. F. Müll.) Ehrbg. was found sparingly in July and August during maximum temperatures. Hempel ('99) reports *S. barretti* Barrett and *S. roeselii* Ehrbg. from the river, but I have not identified them in the plankton collections.

*Strombidium viride* Stein was found in small numbers in January–March, 1899, at minimum temperatures.

*Stylonychia mytilus* (O. F. Müll.) Ehrbg. was found in the plankton sparingly from September to February, and once in June.

*Tintinnidium fluviatile* Stein.—Average number, 22,590 or 1,640,-192*. This species is somewhat sharply limited to the warmer months in its seasonal distribution. In 1898 (Table I.) it makes its appearance April 4 at 49°, reaches a maximum of 720,000 May 3 at 60°, and has three decreasing pulses; one of 104,000 on June 14 at 80°, one of 95,200 on August 2 at 79°, and one of 22,400 on September 27 at 73°, and disappears from the plankton October 18 at 52°. The records in previous years are more irregular, though traces of vernal and midsummer pulses can be found in the records. Filter-paper catches indicate that only one in eighty of this species is retained by the silk. They also locate the pulses as approximately coincident with those of the silk collections.

Apstein ('96) finds *Tintinnidium* to be a spring planktont with its maximum in April in Lake Plön, while Seligo ('00) finds it in lakes near Danzig in the autumn, with a maximum in September. In our own waters in 1896 the autumnal pulse in August–September exceeds the vernal one.

The gelatinous lorica of this species is subject to great variation in its size and proportions, and especially in the region about the aperture. A somewhat thimble-shaped form was described by Hempel ('96) as *T. illinoisensis*, the specific distinctions being based wholly on the lorica. This form intergrades with the typical lorica of *T. fluviatile* Stein, and should not in my opinion be given specific rank.

*Trachelius ovum* Ehrbg.—Average number in 1895, 847. This species did not occur in 1898 but was rather common in November–December, 1895, reaching a maximum of 10,695 on December 4 at 32.5°. Isolated appearances in small numbers in December and January of other years have been recorded. In our waters it is thus a winter planktont. Stagnation conditions under the ice were approaching (Pt. I., Pl. XLIII.) when the pulse of 1895 occurred in the Illinois River. Apstein ('96) found it, however, in Lake Plön with a maximum in May–June, disappearing in the summer and returning again in November.

*Trichodina pediculus* Ehrbg.—Average number, 1; in 1897, 874. This species is normally found upon *Hydra*, on the gills and skin of amphibians, and on young fish. It appears in the plankton during the summer months in every year except 1898, a single record only being made in that year. The earliest record was on June 11, and the latest on November 31. The whole temperature range is practically included in these occurrences, though the species disappears within a few weeks after the temperature falls below 50°. It usually appears in small numbers and irregularly, and no pulses like those of typical planktonts can be traced. A free life in the plankton is apparently not its usual habit. Zacharias ('00) has recently called attention to its appearance in the plankton in German waters.

*Vorticella rhabdostyloides* Kell.—Average number, 61. This little *Vorticella* is found attached in small clusters to *Anabæna spiroides* and occasionally to other members of the phytoplankton. It is somewhat common in the waters of Lake Michigan, but is rare in spring months in the Illinois River.

*Vorticella* spp.—Average number, 7,843. At irregular intervals from April to November isolated individuals and small clusters attached to bits of debris in the silt were taken in the plankton. They were most abundant at temperatures above 50°. The irregularity in their occurrences indicates that they are adventitious in the plankton. Identifications of plankton material are impracticable except in strongly marked species. Hempel ('99) has found *V. campanula* Ehrbg., *V. microstoma* Ehrbg., and *V. similis* Stokes in the river and its adjacent waters.

*Zoöthamnium arbuscula* Ehrbg.—A few colonies were taken in August and September in 1896 in the plankton, probably adventitious during the disturbed hydrograph of that year (Pt. I., Pl. X.).

The preceding list of 45 species does not complete the catalog of the ciliate constituents of the plankton, though it includes all of the species of quantitative importance during the years of our operations. The residium of unidentified ciliates, which, excluding the partial identifications in the above list, does not often exceed two per cent. of the total individual ciliates, includes principally isolated individuals of species difficult of identification or others whose preservation did not permit it, and a considerable number of small ciliates and of forms ectoparasitic upon *Entomostraca* and other planktonts. Most of these organisms are either adventitious or passive members of the plankton, and further study of the littoral region, of stagnating waters, and of these parasitic forms will reveal the great richness of the ciliate fauna in this aquatic environment.

## SUCTORIA.

Average number, 332. This class is not quantitatively important in the plankton, being represented, in so far as our records go, only by adventitious or passive planktonts. No limnetic species has as yet been found in the Illinois. An examination of the littoral region during the prevalence of ciliates will probably yield a rich suctorian fauna.

### DISCUSSION OF SPECIES OF SUCTORIA.

*Acineta linguifera* Clap. and Lach.—This species is usually found on aquatic *Coleoptera*. A single occurrence of an unattached individual was recorded June 21, 1898.

*Metacineta mystacina* Ehrbg.—Average number, 301. This species occurred in the plankton from March till October in 1898 and in the winter months of 1899, at irregular intervals and in small numbers (Table I.). Most of its occurrences attend flood invasions, and it is evidently adventitious. It is frequently attached in the plankton to minute particles of debris. This species varies greatly in the size of the lorica. Sand ('01) gives the range in height as from 33–700 $\mu$. The variation in proportions has given rise to a number of descriptions of new species by Stokes ('88 and '94) and Maskell ('87), but an examination of a series of individuals such as appear in the plankton shows that they intergrade so closely that specific distinctions can not be maintained for the variants. *Metacineta* appears throughout the whole range of temperatures, no seasonal predominance appearing in the records.

*Podophrya fixa* O. F. Müll.—Average number, 12. This species is also adventitious in the plankton. It was recorded in March and September at 37° and 73°. Cysts were noted January 21.

*Tokophrya quadripartita* Clap. and Lach.—Average number, 4. Adventitious in the plankton in March and November. Hempel ('99) finds it most abundant in May and June, associated with *Epistylis plicatilis* and *Opercularia irritabilis* on crayfish, insect larvæ, and turtles.

*Tokophrya cyclopum* Clap. and Lach.—Found occasionally upon *Cyclops* during spring and summer.

## PORIFERA.

*Spongilla* spp.—Average number of spicules, 772. The identification of fresh-water sponges by isolated spicules is practically impossible, and, moreover, the sponge fauna of the Illinois River is as yet practically unknown. No attempt, therefore, was made to identify the species to which the spicules which occur in our plankton collections belong. They belong to the genus *Spongilla* in part, and were usually the simple sarcode forms, the gemmules or their spicules not appearing in the plankton. They occurred in all months of the year, and were found in 46 per cent. of the collections. They are adventitious, and their occurrence in the plankton is therefore dependent in part upon hydrographic conditions. Records in December and January are few (3) and always occur on rising floods. In February and March, months of rising floods, they are increased (8 and 7), but decline again in April–June (3, 5, and 5), months of predominantly declining water and more stable conditions. In midsummer and autumn months (July to November) they again occur more frequently (8 to 12), probably as a result of proximity to the season of greatest growth and frequency of sponges in the river and its backwaters. Here also they occur most frequently in years of greatest hydrographic disturbance, as, for example, in 1898. The adventitious relation which they bear to the plankton is also seen in their erratic and irregular numbers. The maximum record (16,000 per $m.^3$) was made June 28, 1897, on the rising flood; the next in size, on August 10 in stable low water. In both instances the plankton was probably taken from water in which as a result of some local disturbance the remains of some disintegrating sponge had been distributed. Living sponges are found in considerable abundance on submerged brush and timbers in the channel and backwaters during the summer months, and feed on the smaller organisms of the plankton, being one of its depleting agencies.

## CŒLENTERATA.

*Hydra fusca* L.—Average number, 39. *Hydra* occurred in about 16 per cent. of our channel collections—a percentage which would be considerably increased if the whole of each collection had been examined for it, or if backwater collections should be included. With one exception the 28 occurrences recorded, all fall in May–September at temperatures rarely below 70°. The earliest record in channel waters was on May 1, 1896, at 68.75°, and the latest on November 15, 1897, at 47°. Of the 28 records in channel waters the months from May to September have, respectively, 6, 3, 10, 7, and 1 record, and there is 1 in November. *Hydra* is thus a late vernal and a summer planktont in our waters.

Observations in the field and a cursory examination of the collections made in the backwaters have indicated that *Hydra* is often very abundant on the vegetation. It is also limnetic in habit, floating with the foot attached to the surface film and tentacles widely extended; or, without attachment, in the deeper strata of water. A similar limnetic habit was often observed in the case of *Hydra* in channel waters, especially on still warm days when the surface was unruffled.

*Hydra* was generally more abundant in the plankton in May or in early summer. The maximum record in channel waters was 3,200 per m.³ on July 21, 1897, the error of dilution being, however, large in this record. In Quiver Lake on May 8, 1896, a maximum record of 5,335 per m.³ was made, the error of dilution being very small. This was during a vernal plankton pulse (8.14 cm.³ per m.³) in these waters, when the food of *Hydra* was present in considerable abundance.

*Hydra viridis* L. was seen frequently in spring-fed backwaters and in laboratory aquaria, but was never recognized in plankton collections made in channel or backwaters. The limnetic habit noted in *H. fusca* was not observed in the case of this species.

## PLATYHELMINTHES.

### TURBELLARIA.

Numerically and from the volumetric standpoint the *Turbellaria* are not of great significance in the plankton of fresh waters as a rule. However, in some seasons and under certain conditions *Stenostoma* becomes very abundant, as, for example, in autumn months in backwaters, and generally where decaying vegetation abounds. In the autumn of 1895 the plankton in the relict pools of Flag Lake consisted almost entirely of *Synura uvella*, *Stenostoma leucops*, and *Entomostraca*.

The average number in channel waters is 103 per $m.^3$, and, as might be expected, their occurrences are erratic in seasonal distribution and their numbers are irregular. They occurred in channel waters in every month of the year and throughout the whole seasonal range in temperatures. The numbers in 1898 were larger and occurrences more frequent in May, during the run-off of the spring flood, and smaller and more erratic during the rest of the year. In the total of all collections enumerated the percentage of occurrences was highest in June (60 per cent.), July (83 per cent.), August (48 per cent.), and October (47 per cent.), and lowest in colder months, when it rarely rises above 30 per cent. The numbers are also larger in the warmer months, a maximum record of 19,250 per $m.^3$ on September 4, 1894, following a slight rise in river levels at low stages. The adventitious character of the *Turbellaria* in channel plankton is suggested by the erratic data, but the adaptability, at least of certain species, to the limnetic habit under certain conditions is also indicated by the large numbers.

The identification of the *Turbellaria* in plankton collections is not feasible in the course of the usual methods of examination of preserved plankton. Accordingly no effort was made to identify the individuals occurring in our catches. Many of them were evidently rhabdocœle turbellarians, and of these probably many were *Stenostoma leucops*. The genus *Vortex* was also represented.

*Mesostomum ehrenbergii* O. Schmidt was taken in small numbers on August 26, 1895, along the shores of the river in vegetation. This identification is that of Dr. W. McM. Woodworth ('97).

*Stenostoma leucops* O. Schmidt.—Average number, 21. By far the greater proportion of the turbellarians in our collections probably belong to this species. The statements made regarding the group as a whole therefore probably apply to this species.

## TREMATODA.

Many of our predaceous fishes and other aquatic vertebrates are infested to an extraordinary degree by flukes parasitic in the intestine or other viscera. This, in conjunction with the fact that the fish markets are located in house-boats along the stream and their refuse generally cast directly into the channel, is sufficient to account for the few adventitious adult distomes which have been noted in our plankton collections. They have occurred singly in February and July, but were not identified.

The free-swimming larval stages or cercaria of unidentified trematodes were also found singly in August, September, and October.

*Aspidogaster conchicola* v. Baer, which occurs abundantly in the mantle cavity and pericardium of many of the *Unionidæ* (see Kelly, '99), which form great beds on the river bottom, was taken in an immature condition in the plankton on June 27.

*Cotylaspis insignis* Leidy, likewise a parasite of the *Unionidæ*, associated with *Aspidogaster* but confined principally to the mantle chamber, was taken in the plankton on February 4.

### CESTODA.

*Tetrarhynchus* sp. was adventitious in the plankton on June 27, and doubtless of similar origin to the adult trematodes above noted.

### NEMERTINI.

Fresh-water nemerteans were definitely identified as such in the plankton on only two occasions, July 23, 1894, and March 22, 1897. They were doubtless adventitious—from the shore or bottom, where they are most abundant.

## NEMATELMINTHES.

### NEMATODA.

The free-living nematode worms are predominantly shore and bottom forms, living in the midst of the decaying organic matter of the bottom ooze. In a habitat such as ours, where the quantity of this decaying matter is very great, the nematodes are correspondingly abundant, and, owing to the unstable hydrographic conditions, they find many opportunities of joining the plankton temporarily. Accordingly we find that nematodes are met most frequently and in largest numbers in rising flood waters, when the bottom deposits of tributaries and the main stream are carried in channel waters as silt. Thus, in the month of March nematodes occurred in 13 of the 15 collections examined, with an average number per $m.^3$ of 465, while in August they were found in but 8 of 21 collections, and averaged only 186 per $m.^3$. So, also, in the winter flood of 1895–96 nematodes were found in the plankton almost continuously till the middle of

April, while in the more stable conditions of the preceding year they were found in only one third of the collections. In 1897 most of the 31 collections examined were made in stable conditions, and nematodes were found in but 5 of these, and 4 of these 5 were made in rising flood waters. In 1898, a year of greater hydrographic disturbance, nematodes occurred in 31 of the 52 collections, averaging 318 per $m.^3$ to 82 in 1897. Of the 31 occurrences in 1898 all but 6 were in recent flood waters. The hydrographic conditions attending the presence of nematodes in the plankton thus indicate that they are adventitious in the plankton. Further evidence of this is to be found in their erratic numbers. Thus, on February 20, 1896, none was recorded, and on the 25th their numbers rose in flood waters to the maximum record for all of our collections—18,422 per $m.^3$

No effort was made to determine the species of these nematodes. A considerable variety of forms awaits the labors of some courageous systematist.

### ACANTHOCEPHALA.

These worms are found abundantly in the *Catostomidæ* and other limophagous fishes of the Illinois River, and in many of the waterfowl which feed in its waters. A chance occurrence of a single specimen in the plankton on August 3, 1896, is probably to be accounted for as in the case of other intestinal parasites.

## ANNULATA.

### OLIGOCHÆTA.

The representatives of this order belong to the smaller aquatic species—generally littoral or limicolous forms found especially in decaying vegetation or among *Lemnaceæ*, and belonging principally to the family *Naididæ*—and usually occur in the plankton in mutilated condition, since autotomy occurs when the preservative is added to the plankton. Specific identification of the fragments is therefore often impossible and usually of questionable certainty. I am indebted to Professor Frank Smith for assistance in such identifications as have been made. The following list (see Smith, '00) gives the relative frequency of the species from which accessions to the plankton are made, with my notes on identified forms in the plankton.

NAIDIDÆ.

*Stylaria lacustris* (L.).—Abundant. Taken in the plankton in April.

*Nais elinguis* O. F. Müll.—Abundant.

This species was identified in the plankton on April 29, 1895, during the decline of the spring flood.

*Slavina appendiculata* (D'Udekem) (*Nais lurida* Timm.).—Frequent.

*Ophidonais serpentina* (O. F. Müll.) (*Nais serpentina* O. F. Müll.).—Frequent.

*Dero limosa* Leidy.—Abundant.

*Dero obtusa* D'Udekem.—Abundant.

This species was taken in the plankton in July and August, 1895, during the run-off of impounded waters from recently invaded backwaters. (See Pt. I., Pl. IX.)

*Dero vaga* (Leidy).—Abundant.

Two individuals (Part I., p. 297) were found in channel waters in stagnation conditions under the ice on February 23, 1895, at a time when the plankton was almost entirely exterminated. Under normal conditions we have no evidence that this species is more abundant in stagnant waters.

*Dero furcata* Oken.—Frequent.

*Pristina leidyi* Smith.—Abundant.

*Pristina flagellum* Leidy.—One specimen.

*Chætogaster limnæi* v. Baer.—Abundant.

*Chætogaster diaphanus* Gruith.—Abundant.

*Chætogaster diastrophus* Gruith.—This is apparently the most abundant species of the order in the plankton,—having been identified in all months but January and May,—especially at times when impounded flood waters are drained off from backwaters, as, for example, in the March flood of 1895.

ÆOLOSOMATIDÆ.

*Æolosoma hemprichii* Ehrbg.—Frequent.

*Æolosoma tenebrarum* Vejdovsky.—Abundant.

*Æolosoma* sp.—Abundant.

For reasons assigned above, the great majority of the oligochætes in the plankton remain unidentified and are included in our records of total oligochætes. These records throw some light on the conditions controlling the occurrence of oligochætes in the plankton and their seasonal distribution.

They occur in all months of the year and throughout the whole seasonal range of temperatures. They appear in the plankton most frequently and in largest numbers in disturbed hydrographic conditions. Thus, of the 31 collections made in 1897, only 6 contained oligochætes, and the average number per $m.^3$ was only 32. Five of the 6 collections containing oligochætes were made during the run-off of flood waters from impounding backwaters. In 1898, a year of much disturbed hydrograph (Part I., Pl. XII.), there were 52 collections, in 35 of which oligochætes occurred with an average number of 76 per $m.^3$ Over 50 per cent. of the non-occurrences of oligochætes fall in the more stable conditions of January, July–August, and December. The seasons of run-off from impounded backwaters are in all years favorable to the occurrence of oligochætes in the plankton. This is in sharp contrast with the nematodes, which appear with rising floods and access of tributary waters. The oligochætes are thus largely adventitious, at times when run-off from vegetation-rich backwaters prevails, and when *Lemnaceæ* and *Ceratophyllum* are washed into the channel by hydrographic changes.

## ROTIFERA.

(Plates III. and IV.)

Average number, 592,416, of which 195,326, or 33 per cent., are eggs, free or carried externally by the parent. Records were kept of males, of females, of females with eggs, of attached and free, summer, winter and male eggs, and of parasitized and dead individuals.

Rotifers occur in every collection and at all seasons of the year. Numbers are uniformly low (below 75,000 per $m.^3$ and often below 15,000) during minimum temperatures from late in December till early in March. At other seasons of the year numbers fluctuate greatly, rarely reaching the level of the winter minimum except occasionally at the depressions between pulses. The curve of seasonal occurrence falls into the form of recurrent pulses (Pl. III. and IV.) previously noted for other organisms. Of these pulses the vernal one in April–May is uniformly high, attaining 3,954,920 per m.³ on April 24, 1896, 2,287,160 on May 25, 1897, and the maximum record of all years, 5,247,800, on May 3, 1898. Pulses in excess of 1,000,000 per m.³ occur 14 times in our records: in July, August, November, and December in 1895; in April, 1896; in April, May, September, and October in 1897; and in May, June, August, September, and October in 1898. There is, apparently, in years or seasons best represented in our records, a tendency for a vernal pulse, often the maximum one of the year, to occur in April–May, and for an autumnal pulse of large amplitude to appear between the last of August and the middle of October. The pulses contiguous to these major pulses of the year are often of considerable magnitude; as, for example, in 1897, when the maximum of September 7 (5,121,000) is followed by another large pulse on October 12 (2,906,400), and in 1898, when the vernal pulse of May 3 (5,247,800) is followed by a June pulse, on the 21st, of large amplitude (2,601,200). The recurrent character of the pulses appears throughout maximum and minimum periods, and may be traced in Plates III. and IV. In the period of 15 months from July, 1895, to October, 1896, there are 10 such pulses, and 6 months in which pulses do not appear. In the 21 months from July, 1897, to March, 1899, there are 18 pulses, and 3 months in which they do not occur. They often coincide with or approximate those of the *Entomostraca* (Pl. III. and IV.) and of the chlorophyll-bearing organisms (Pl. I. and II.).

With the exceptions of the November–December pulses of 1895 at 33° (1,595,359 on November 27 and 1,636,640 on December 11) and the pulse of October 25 (1,048,620) at 48°, no pulse of considerable amplitude is found at temperatures much below 60° in channel waters.

In the discussion which follows, 104 forms are listed, 6 belonging to the *Rhizota*, 6 to the *Bdelloida*, 91 to the *Ploima*, and 1 to the *Scirtopoda*.

## RHIZOTA.

The *Rhizota* by virtue of their fixed habit are represented in the plankton either by adventitious species, torn from their location on water plants or other aquatic substrata by disturbances in the water, or by colonial species with a free-swimming habit, such as *Conochilus*. As represented by the latter type they are of some quantitative importance in the plankton, especially of the backwaters. Average number, 8,796.

DISCUSSION OF SPECIES OF RHIZOTA.

*Apsilus lentiformis* Metsch.—An *Apsilus* doubtfully referred to this species was taken December 25, 1895, and April 29 and July 23, 1896, at temperatures of 41°–78°, in each case with rising river levels.

*Conochilus dossuarius* Hud.—Average number of females, 517. This species was more than ten times as abundant in the collections of 1896 and 1897 as in 1898. Hempel ('99) reports it from January to September, with a maximum in March. In the plankton collections of 1896 I did not record it until June 11, at 73°. It reached a maximum of 25,800 July 18, and another of 142,800 August 15, at 86°, and disappeared from the plankton September 30 at 58°. In 1897 it reappeared May 25 at 66° and reached greatest numbers September 7 at 80°, and was not recorded after the 14th. In 1898 (Table I.) it first occurred March 8, at 37°, and attained its greatest number, 14,400, on September 27 at 73°. In 1899 it returned towards the end of January, under the ice, and continued till the cessation of operations in March. It thus occurs in the Illinois throughout practically the whole range of seasonal and thermal conditions, but not continuously.

Colonies are of few individuals, and isolated individuals are often found in the preserved plankton. Females with 1–4 eggs were taken, and were most numerous during the rise of the pulse. About 4 per cent. of the females observed, were carrying eggs. Males were found on the decline of the pulse of July, 1896.

*Conochilus unicornis* Rouss.—Average number of females 8,208; eggs, 100. Recorded from March 15, at 46°, to July 5, at 80°. A pulse of 8,000 on April 26 and one of 392,000 on June 7 constitute the only fluctuations. It was not found in 1897, and only sporadically, during the summer, in 1896. Females with 1–3 eggs attend the rise of both pulses in small numbers. The colonies of this species also are composed of but few individuals.

*Conochilus volvox* Ehrbg.—Average number of females, 129. A few large colonies were taken March 29 and April 5 at 49°.

*Megalotrocha alboflavicans* Ehrbg.—Colonies of this species are found in numbers on *Ceratophyllum* in the backwaters, and in 1894, when the vegetation was common along the margins of the stream, it was taken in the plankton occasionally.

*Megalotrocha spinosa* Thorpe.—Isolated individuals of this unusual species were taken in small numbers in the plankton in August, 1896, at maximum temperatures, but no colonies were observed. This is one of the largest of the rotifers in the plankton, individuals measuring about 1 mm. in length. The species was described by Thorpe ('93) from Chinese waters; was next reported by Weber ('98) from the neighborhood of Geneva, Switzerland; and its occurrence in the Illinois is, I believe, the third record of its appearance. It affords another illustration of the cosmopolitan nature of the freshwater plankton. In both Chinese and Swiss waters it was associated with *M. semibullata* Thorpe, also from Hong Kong and Brisbane. This latter species occurs in our waters also (Hempel, '99), though it was not taken in the plankton with *M. spinosa.*

### BDELLOIDA.

Average number, 7,807. They were less numerous in 1897, a year of more stable hydrograph, and fully twice as abundant in 1896, when river levels were much disturbed during summer months. In their seasonal distribution, save for the increase of *Rotifer tardus* in the winter of 1898, the bdelloid rotifers reach their greater numbers in the plankton in the period from March to November. There is a trace of a vernal pulse in April–May (Table I.), and some irregular summer fluctuations, attributable in the main to floods. Their temperature optimum seems (except in the case of *R. tardus* above noted) to lie above 50°. They are as a rule adventitious in the plankton, owing their presence in some cases to floods, though the vernal increase can not in most cases be attributed directly to this disturbance. The species are difficult to identify in preserved plankton material, and the list here cataloged is small. Examination of living plankton would considerably extend the list of forms.

#### DISCUSSION OF SPECIES OF BDELLOIDA.

*Philodina citrina* Ehrbg. was found in the plankton but once—September 14, 1897.

*Philodina megalotrocha* Ehrbg.—Average number of females, 351. This species was found in the plankton (Table I.) from March 15, at 46°, to November 8, at 45°. The distribution in previous years fell within these limits excepting a single record December 29, 1896, at 35°. The lower temperature limits are thus near 45°, and the numbers are all small below 60°. The occurrences are never in very large numbers, and significant pulses do not appear—an indication that the species is adventitious in the plankton. The relative numbers in different years is suggestive. In 1896, with a total movement in river levels of 45.7 feet, the average number per collection is 770; in 1897, with a total movement of 44.8 feet, the number is 271; and in 1898, with 67.2 feet, it is 351. In 1896 a much greater proportion of the change in levels took place (Pt. I., Pl. XI.) during the summer, when *P. megalotrocha* is present. With this in mind, it is apparent that a disturbed hydrograph tends to increase the number of this species in the plankton. A comparison of the individual occurrences (Table I.) with contemporaneous conditions of the hydrograph (Pt. I., Pl. XII.) in 1898, and in previous years also, shows that most of the larger records were made in planktons from a rising river. For example, the largest record made—8,000 on September 27, 1898—is on the crest of a slight rise (Pt. I., Pl. XII.). Some, however, appear in stable conditions, and may be attributed to the other causes of disturbance of the bottom and littoral fauna which tend to bring its constituents temporarily into the domain of the plankton.

*Rotifer neptunius* Ehrbg.—Average number, 425. This species was found in the plankton in every month of the year but February, and thus throughout the whole temperature range. Between November and March the records are scattered and the numbers small, while it is continuously present in larger numbers from March (50°) till late in October (50°–60°). The optimum temperatures thus seem to lie above 50° in our waters. The largest numbers recorded (22,224, April 29, 1896, at 72°, and 6,400, May 17, 1898, at 64°) attend the vernal volumetric pulse. Aside from this season, well-defined and symmetrical pulses are rarely traceable in the small numbers recorded. Some of the larger records, for example that of July 28, 1896 (10,200), attend rapidly rising water, but dependence generally upon this agency for presence in the plankton is less directly evident in this species than in the preceding. As also in the case of *R. tardus*, the average number (246) in 1897, a year of more stable hydrograph (Pt. I., Pl. XI.), is greatly exceeded by that in 1896 (2,323), when the hydrographic conditions during summer were much disturbed (Pt. I., Pl. X.).

*Rotifer* spp.—Average number, 199. Some bdelloid rotifers unidentified because of the state of their contraction, or not even questionably referable to other species listed, are here included. It is quite probable that some individuals belonging to the genera *Philodina* and *Callidina* are among the number. The occurrences are irregular. They exhibit a distribution with respect to years similar to that noted in the two species just discussed. Vernal pulses are noticeable in 1896 on April 29 (19,446), on April 27, 1897 (28,800), and May 3, 1898 (3,200). Egg-bearing females were noted in the winter months of 1899, in December and March of the preceding winter, and in April, 1896. Individuals parasitized by *Endophrys rotatoriorum* Przesm. (?) were noted in April, 1896.

*Rotifer tardus* Ehrbg.—Average number, 6,688. This is the most abundant of all the bdelloid rotifers in our plankton, outnumbering all the others in 1898 six to one. This was due to a sporadic and unusual pulse of individuals in the plankton in midwinter under the ice in 1898. Owing to this, the average number in 1898 exceeds that in previous years. If, however, the large numbers in January and February, 1898, be reduced to normal winter proportions—no record in 1896 in this season exceeds 7,000—the average for the year falls to about 3,500. The average of occurrences in the plankton for 1896, 1897, and 1898 would then be 5,201, 1,254, and 3,500, which approximates somewhat the ratios of the relative disturbance of the hydrograph in these years (Pt. I., Pl. X.–XII.). The agency of flood water in affecting the numbers of this species in the plankton is to some extent indicated by this ratio. It is also apparent on comparison of the seasonal distribution (Table I.) with the hydrograph for 1898 (Pt. I., Pl. XII.). The large numbers of January, February, and March appear in every case with rapidly rising water, and the same is true of the numbers on August 9 (12,000) and September 13 (17,-500). Other disturbances than those due to floods, or other factors than disturbances in the water, must be invoked to explain such increases as one to 12,800 in April–May, 1898 (Table I.). This attends the vernal volumetric pulse (Pt. I., Pl. XII.), but does not conform to its proportions. It appears in the more stable conditions of declining flood, and no adventitious factor is apparent to account for its development to such numbers in the plankton. The winter pulse was attended by large numbers of ovigerous females, but none was recorded during this vernal pulse. A somewhat similar increase in stable conditions was found in March and April, 1896, from 40°–72°. Temperatures of 50°–70° were several weeks earlier than usual this year, but the increase in *R. tardus* came at lower temperatures than in 1898.

As above stated, this winter pulse, or, rather, sequence of three pulses (Table I.), culminating January 25 (89,397), February 15 (27,000), and March 15 (19,200), came with floods. No such increases attended the somewhat similar hydrographic conditions (Pt. I., Pl. XIII.) of 1899 nor the winter flood of 1896. There is nothing in the evironmental data to explain this unusual occurrence. An unusually large number of females with eggs still attached to the body were seen in the period from January 21 to April 12. Fifty per cent. were ovigerous, carrying a single egg. Numbers of similar free eggs were also noted. Rapid multiplication of the species at the time of these pulses is thus suggested, and these may be dependent upon favorable conditions of nutrition of whose nature no clue is suggested. The species is in the main adventitious, with insufficient evidence of a partially limnetic habit at some seasons.

The species occurs in almost every one of the plankton collections, and thus throughout the whole range of temperatures and environmental conditions. The largest numbers were taken during minimum temperatures under the ice; but large numbers also appear at other seasons, and no temperature optimum is definitely indicated, though in years prior to 1898 the larger numbers and more regular occurrences are to be found in the period from March to November at temperatures above 50°.

*Rotifer vulgaris* Schrank.—Average number, 275. This species has a seasonal distribution—though in smaller numbers and fewer occurrences—which corresponds somewhat closely with that of *R. neptunius* (Table I.). The same factors in the environment are presumably operative in modifying its appearance in the plankton.

Hempel ('99) finds *R. macrurus* Schrank, *Philodina macrostyla* Ehrbg., and *Callidina elegans* Ehrbg. in the plankton of Quiver Lake, adjacent to the river.

### PLOIMA.

Average number, 571,611, including eggs, which constitute about 30 per cent. These rotifers occur at all seasons and are found in every collection. They are quantitatively the most important order of the *Rotifera*. They include about 97 per cent. of the individuals and almost all of the limnetic species.

As a group they exhibit a seasonal routine which is a complex of the records of individual species, and as such it reflects to a remarkable degree a similarity to individual records, especially of the perennial species. In general the *Ploima* are less abundant in colder months, that is, below 50°–60°, than in the warmer ones from May to October. Midwinter numbers are nevertheless considerable,—5,000–35,000,—and with the first rise of temperature in March we have, in 1898, a pulse of 175,000 which declines and again rises in a vernal pulse of April–May, which vies with an autumnal pulse for rank as the annual maximum. Following the vernal pulse there comes a series of summer movements which vary from year to year. In 1898 they grow smaller as the season wanes, rising again in September. In 1897 the autumnal pulse is the largest of the year and appears early in September. In 1895, on the other hand, it is carried into the last days of November. Numbers sink to the winter minimum shortly after the winter temperatures are reached. In a general way the direction of movement in the several parts of the seasonal curve of the total *Ploima* is much like that of the individual species of which it is composed. The differences lie in the amplitude of the pulses and in slight changes in the locations of maxima and minima. There are, it is true, many exceptions to this sweeping general statement, but it is, nevertheless, both surprising and significant that the sum of so many complex records should still preserve the recognizable outlines of its parts. This is not due simply to the dominance of a few abundant species, but is a combination of many, as will be seen frequently in Table I., where species with insignificant numbers still show in their seasonal occurrences some correlation with the movement of the great mass of the totals. This similarity points to some common factor in the environment common to all of the species. It is to be found, I believe, in the food relations—in the wax and wane of the food supply. Most, if not all, ploiman rotifers are herbivorous, or at least omnivorous, and find their food to a large extent in the phytoplankton. I have already called attention to the recurrent pulses of the chlorophyll-bearing organisms. These primarily, but combined with other and largely changing seasonal factors such as hydrograph and temperature, are the basis upon which the superstructure of the seasonal changes in the ploiman plankton are built. The correlation between

Pulses of Ploima, excluding Eggs.

| Year | Date | No. | Date | No. | Date | No. | Date | No. | Date | No. | Date | No. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1894 | —— | —— | —— | —— | —— | —— | —— | —— | —— | —— | —— | —— |
| 1895 | —— | —— | —— | —— | —— | —— | Apr. 29 | 566,015 | —— | —— | —— | —— |
| 1896* | Jan. 6<br>" 25 | 28,302<br>12,312 | —— | —— | —— | —— | Apr. 24 | 3,844,548 | May 8<br>" 25 | 295,411<br>116,640 | June 17 | 222,400 |
| 1897 | —— | —— | —— | —— | —— | —— | —— | —— | May 25 | 1,641,080 | —— | —— |
| 1898 | Jan. 25 | 19,017 | —— | —— | Mar. 22 | 138,480 | —— | —— | May 3 | 3,243,000 | June 21 | 1,636,900 |
| 1899 | Jan. 17 | 28,320 | Feb. 14 | 178,000 | Mar. 7 | 81,520 | | | | | | |



| Year | Date | No. | Date | No. | Date | No. | Date | No. | Date | No. | Date | No. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1894 | —— | —— | Aug. 15 | 391,049 | —— | —— | Oct. 17 | 67,545 | —— | —— | —— | —— |
| 1895 | July 6 | 630,700 | Aug. 12 | 1,063,456 | Sept. 12 | 80,884 | | | Nov. 27 | 1,299,687 | Dec. 11 | 1,174,480 |
| 1896 | July 10<br>" 23 | 198,040<br>229,800 | Aug. 26 | 119,640 | —— | —— | —— | —— | —— | —— | —— | —— |
| 1897 | July 21 | 495,200 | —— | —— | Sept. 7 | 3,033,000 | Oct. 12 | 1,750,800 | Nov. 9<br>" 30 | 48,500<br>95,040 | Dec. 14 | 81,000 |
| 1898 | July 19 | 644,360 | Aug. 2<br>" 16 | 655,240<br>548,800 | Sept. 27 | 1,292,800 | Oct. 25 | 925,120 | Nov. 15 | 115,200 | Dec. 20 | 130,120 |

*In this and subsequent tables of similar nature, the first or last, respectively, of the two dates given for a first or last record is an isolated one prior or subsequent to the season of more continuous occurrence.

the seasonal distribution of individual species and these recurrent plant pulses will be discussed in connection with the various species wherever the data are available. For the present it will suffice to call attention to such correlation as exists between fluctuations of the phytoplankton and the total *Ploima*. The table on the preceding page gives the location and amplitude of the maxima of the ploiman pulses, and a graphic presentation of the seasonal curve of distribution of the total *Rotifera* will be found in Plates III. and IV. On comparison of the ploiman pulses with those of the chlorophyll-bearing organisms, graphically presented in Plates I. and II., it will be found that 15 of the 33 pulses of *Ploima* contained within the period covered by the plates coincide in location with the plant pulses; that 12 follow at the next collection, usually a week later, and 3 within a fortnight; while only 3 of the 33 exhibit no such correlation. The data suggest strongly the agency of the plant pulses in building up the *Ploima*, and that the food relations are fundamental in the fluctuations of these planktonts.

DISCUSSION OF SPECIES OF PLOIMA.

*Anuræa aculeata* Ehrbg.—Average number, 1,839. In 1898 this species has a very well-defined and characteristic seasonal distribution (Table I.). It first appears March 8 at 37°, increases to a maximum of 45,200 on May 10 at 61°, then declines, and disappears June 14 at 83°. The curve of its occurrence in this year is a very symmetrical one. It reappears on December 27 at 32°, and there are scattered occurrences through the winter months of 1899. Records in other years suggest in the main a similar distribution. In 1896 it first appeared January 6, rose to a pulse of 6,550 on May 8 at 76°, and, on the decline of the June rise, there was a second and larger pulse of 29,600 on June 17 at 76°. It reappeared on December 29, and in 1897 reached a vernal maximum of 22,400 on May 25 at 66°, then disappeared, and was not again noted in the following winter nor until March 8. In 1894 the last vernal record was made June 12, and on September 4, at 78°, there was an autumnal pulse of 13,825—a phenomenon not repeated in subsequent years. The normal course of its seasonal distribution in the river plankton seems to be as follows: reappearance in December when minimum temperatures have been reached; slow multiplication during the winter, and a well-defined pulse on the decline of the spring flood in

April–May with the possibility of a second on the June rise; and prompt and complete disappearance when maximum summer temperatures are established. Low water in the autumn seems to interfere with an autumnal pulse. In 1894 there was a well-sustained rise in September (Pt. I., Pl. VIII.) and a pulse of *A. aculeata.* In 1896, however, no pulse occurred in the high water of the autumn. No midwinter occurrences followed the very low water of 1897. It is thus in channel waters a vernal planktont, with its temperature optimum near 70° but below the summer maximum. Hempel's statement ('99) that it is a "winter species" is borne out by its presence from December through the winter, but its numerical distribution ranks it at once with the vernal organisms. Lauterborn ('94) finds it abundantly in winter months in the Rhine, and Apstein ('96) speaks of it as a "Sommerform," absent from Lake Plön from November till March, and with maxima from April to July in different bodies of water where it continues through the summer and till October, and then disappears. Summer temperatures in these waters, however, are not recorded by him above 21° C. (69.8° F.), which is about the temperature at the time of the vernal maximum in the Illinois, and at least 10° F. below that of the summer maximum in our waters. Jennings ('94, '96, and '00) records it as abundant in the summer plankton of Lake Erie, Lake Michigan, and some inland lakes of Michigan. These waters also are somewhat cooler (5°–10° F.) than those of the Illinois River in midsummer. Temperature, it seems, must have a decided effect upon the seasonal distribution of this organism in our waters, though the chemical conditions and food supply may also enter as factors in the summer suppression of the species.

Females carrying usually a single egg appeared in 1898 early in April, and were most abundant during the maximum of the pulse. On an average, less than a fourth of the females were ovigerous. Empty loricæ appeared May 10 (4,800) and 17 (3,200) at the crest and decline of the spring pulse, and the same phenomenon of decadence was noted in previous years during this period. Outbreaks of parasites were not recorded for the species, and the decline is to be attributed to cessation of reproduction and to the death and destruction of the individuals by the more usual causes.

This species is quite variable, but no effort was made to follow its seasonal history. The type form is by far the most abundant.

*A. aculeata* var. *valga* Ehrbg. was seen frequently. *A. serrulata* Ehrbg., regarded by Weber ('98) as a variety of *A. aculeata*, was recorded Jan. 24, 1899, and found by Hempel ('99) in December. It seems to be rare in our plankton. Forms approaching *A. aculeata* var. *brevispina* Gosse were also noted, but they, too, are rare, being recorded only in February and March, 1899. *A. aculeata* var. *curvicornis* Ehrbg. was noted April 29, 1896, at 70°.

*Anuræa cochlearis* Gosse.—Average number, 69,393, distributed as follows: *A. cochlearis* (*sensu strictu*) together with *A. cochlearis* var. *macracantha* Lauterborn, 9,421; *A. cochlearis* var. *tecta* Gosse, 15,432; and forms with posterior spine of intermediate length between *cochlearis* and *tecta* which include *A. cochlearis* var. *stipitata* Ehrbg., 44,540. Numerically this is one of our important species, containing over one ninth of all the rotifers in 1898. It is surpassed only by *Brachionus bakeri* (with varieties included), *Polyarthra*, and *Synchæta*. Average number of eggs, 32,358.

This is a perennial planktont, appearing in every month of the year throughout the whole range of temperature. Its entire absence in August, 1898 (Table I.), is not paralleled in any other year. In 1897, for example, there is a well-developed pulse of 45,600 on August 24. In 1894, 1895, and 1896 there is a midsummer minimum of a few weeks' duration in July, August, or September, but it is irregular in its location.

While the appearance of sexual cycles was not traced by the records of males and winter eggs,—a matter of some difficulty and uncertainty in preserved plankton material,—the existence of such cycles is suggested by the recurrent pulses of occurrence in this species (Table I.). It is possible that the species is polycyclic in our waters. The pulses in 1898 are well defined, in fact, somewhat better than in previous years. The following table gives the numbers in the pulses in the several years and the dates and temperatures at which the maxima occurred.

All of the large pulses save those of November and December and one at the close of October (Oct. 25, 1898, 28,500) lie at temperatures above 60°. The vernal pulse of April–May is the largest and appears between 60° and 70°, and the amplitude diminishes as the period of maximum heat progresses, though in 1898 there was a recurrence of larger numbers as temperatures fell. The optimum

PULSES OF ANURÆA COCHLEARIS.

| Year | Date | Temp. | No. | Date | Temp. | No. | Date | Temp. | No. |
|---|---|---|---|---|---|---|---|---|---|
| 1894 | —— | —— | —— | June 12 | 78° | 1,344 | —— | —— | —— |
| 1895 | Apr. 29 | 64° | 180,480 | —— | —— | —— | July 18 | 80° | 17,805 |
| 1896 | May 8 | 76° | 100,870 | June 11 | 73° | 95,200 | July 2<br>" 28 | 81°<br>81° | 12,800<br>17,600 |
| 1897 | May 25 | 66° | 620,800 | —— | —— | —— | July 21 | 82° | 37,600 |
| 1898 | May 10 | 62° | 1,145,600 | June 21 | 77°. | 372,800 | July 19 | 84° | 17,200 |

| Year | Date | Temp. | No. | Date | Temp. | No. | Date | Temp. | No. |
|---|---|---|---|---|---|---|---|---|---|
| 1894 | —— | —— | —— | Sept. 4 | 78° | 7,350 | —— | —— | —— |
| 1895 | Aug. 21 | 83° | 17,805 | Sept. 23 | 76° | 1,521 | Nov. 20 | 44° | 1,120 |
| 1896 | Aug. 21 | 79° | 5,600 | Sept. 16 | 71° | 6,224 | Dec. 29 | 35° | 3,840 |
| 1897 | Aug. 24 | 78° | 45,600 | Oct. 5 | 70° | 4,800 | —— | —— | —— |
| 1898 | —— | —— | —— | Sept. 27<br>Oct. 25 | 73°<br>48° | 54,400<br>28,500 | Nov. 21 | 40° | 10,000 |

conditions seem thus to be found in the river at temperatures somewhat below the maximum, between 60° and 70°.

The phenomena of recurrent pulses are distinctly traceable in the seasonal distribution of this species, not only in 1898 (Table I) but also in preceding years. The large May and June pulses of 1898 appear on the declines of the spring and the June rise, respectively; the pulse of September 27 is in a falling river; and that of October 25, on a slowly rising flood (Pt. I., Pl. XII.). In 1897 (Pt. I., Pl. XI.) the first two pulses attend the spring flood and June rise in like manner, but the two subsequent pulses are in stable low water. In 1896 five of the seven pulses lie on the declines of the recurrent floods of that year and two in rising waters (cf. Pl. X. of Pt. I. and the table just given). In 1894 and 1895 the pulses appear either in falling water or in the earliest stages of the rise. The number of pulses on declining waters is somewhat greater than the relative number of days of this condition would lead us to expect, and it seems probable that optimum conditions for the appearance of larger numbers of *Anuræa cochlearis* are to be found in such hydrographic conditions. The run-off of impounded backwaters is one of the favorable phases during flood decline. On the other hand.

the distribution of the pulses with reference to the floods and the appearance of pulses during rising water suggest the operation of other factors than the one arising from contribution from backwaters.

The pulse must be dependent to a large extent upon food supply of the organism, and a correlation between its periods of multiplication and the pulses of its food, the chlorophyll-bearing organisms, is to be expected. A comparison of the seasonal distribution in 1898 (Table I.) and the pulses of chlorophyll-bearing organisms (Pl. II.) reveals the fact that three of the *A. cochlearis* pulses coincide with those of the plants constituting their food, and the other three coincide in part only, the remainder of the chlorophyll-bearing groups reaching their culmination a week prior to that of the rotifer. In 1897 the three pulses of *A. cochlearis* which lie in the common period (Pl. II.) all culminate a week (in one case in part in fourteen days) after the maximum of the plants in question. In 1896, three pulses coincide and three follow in the subsequent collection; and in 1895, two coincide and two follow. Collections at daily intervals would be necessary to follow the correlation more accurately. It is probable from these juxtapositions and sequences in the *A. cochlearis*-algæ pulses that we are dealing with a food relation. Multiplication of algæ leads to increase of *Anuræa*, which, in turn, reduces the algæ, and then itself declines until the food planktonts again increase.

*Anuræa cochlearis* is exceedingly variable in the length of the posterior spine, in the development and degree of curvature of the anterior spines, in the arrangement of the areas of the lorica, and in the degree of its ornamentation by small spinules. The separation of these varieties where every individual must be assigned to some one of them, is a matter of some difficulty owing to the presence of intergrading individuals. The characters which signalize var. *hispida* Lauterborn and var. *irregularis* Lauterborn are not quickly recognized under the conditions of rapid plankton enumeration, and no effort was made to trace their seasonal distribution in our plankton. Lauterborn's var. *macracantha* was included with the type form—his var. *typica*—in our records. These two include those individuals with medium-sized and longer posterior spines. In our waters the variety *macracantha* is relatively rare, at least as figured by Lauterborn ('98). Indeed, both the type and this variety constitute less than a seventh of the total representatives of the species. Their distribution throughout the year (Table I.) accords with the results obtained by Lauterborn ('98), who found that the average length of the posterior spine from January to May and from October to December was from 78 to 48 $\mu$, while from June to September it was from 28.5 to 21 $\mu$. In Table I. it will be seen that the longer-spined forms which I have referred to *A. cochlearis* var. *macracantha* and var. *typica* occur in the plankton from January to May 31, and then disappear, returning again, in small numbers, October 25. The short-spined variety referred by me to *A. cochlearis* var. *stipitata* and the spineless var. *tecta* are, on the other hand, continued during the summer. The natural result would be that the average length of the spines in the species as a whole would fall during the summer months. It is apparent that this tendency on the part of *A. cochlearis* to become shorter and smaller during the summer months does not bear out the contention of Wesenberg-Lund ('98) that winter individuals are smaller and summer ones larger among perennial rotifers. He reports var. *tecta* as "die Hauptform des Winters" in several Danish lakes, and the variety with a long horn as a *summer* form, found in July–August.

Of these varieties, *macracantha*, *typica*, and *stipitata* intergrade in our waters with numerous connecting links, while var. *tecta* is not connected with the other forms by many individuals with intermediate characters. Lauterborn ('98) also notes the greater independence of this variety in the waters of the Rhine.

In Table I. the seasonal distribution of these three varieties, the long-spined (*typica* and *macracantha*), the short-spined (*stipitata*), and the spineless (*tecta*) are given separately. It will be noted that the long-spined form has the distribution above mentioned, that var. *tecta* runs throughout the whole year, and that var. *stipitata* is absent in midwinter and is a common summer form. The relative numbers of the varieties fluctuate in different years. For example, var. *tecta* was relatively but one fourth as abundant in 1897 as in 1898. As shown in Table I., whenever coincidently present in the plankton all the varieties respond to the causes which produce the rhythm of occurrence, the rise, culmination, and decline of the pulses being much alike in all of the varieties.

About three eighths of the females noted in 1898 were ovigerous, carrying as a rule but a single egg. Instances of two eggs were noted, but they are rare. The greatest proportion of egg-bearing females appears during the rise of the pulse, as is seen in the following table, which gives the data of the vernal pulse in 1898. From

ANURÆA COCHLEARIS.

| Date | No. of ovigerous females | Total females | Total eggs | Ratio of eggs to individuals | No. of dead |
|---|---|---|---|---|---|
| April 12. . . . . . . . . . . . . . | 800 | 2,200 | 800 | 1 : 2.75 | 0 |
| April 19. . . . . . . . . . . . . . | 6,400 | 15,200 | 8,800 | 1 : 1.73 | 400 |
| April 26. . . . . . . . . . . . . . | 45,000 | 137,800 | 65,000 | 1 : 2.12 | 3,200 |
| May 3. . . . . . . . . . . . . . . | 536,000 | 1,022,400 | 552,200 | 1 : 1.85 | 9,600 |
| May 10. . . . . . . . . . . . . . | 489,600 | 1,145,600 | 643,200 | 1 : 1.78 | 99,200 |
| May 17. . . . . . . . . . . . . . | 110,400 | 434,800 | 160,000 | 1 : 2.71 | 100,000 |
| May 24. . . . . . . . . . . . . . | 6,000 | 21,200 | 7,200 | 1 : 2.94 | 1,800 |
| May 31. . . . . . . . . . . . . . | 3,000 | 11,200 | 3,400 | 1 : 3.29 | 1,800 |

April 12 to the crest of the pulse on May 10 (not inclusive) the average ratio of eggs to individuals was 1 to 1.87. From the crest to the foot of the decline inclusive the ratio is 1 to 2.98. The number of empty loricæ is given below, and it will be noted that on the week prior to the crest of the pulse there were 107 living to one dead; on the crest itself, one to twelve; while the week following the crest of the pulse there was an empty lorica for every 4.3 living females. Rapid multiplication thus attends the rise of the pulse and rapid destruction its decline. Parasites were very rarely observed in this species. The decline of a pulse is thus due to the cessation of reproduction and a relatively heavy death rate.

Apstein ('96) finds that in Lake Plön *Anuræa* reaches its maximum in July and is at its minimum in April. It is everywhere common in the German waters. *A. tecta*, on the other hand, was found only in the smaller lakes and in great numbers, replacing *cochlearis* in warmer months to some extent. Lauterborn ('98) regards it as the most abundant rotifer in the Rhine. Our statistical records do not show that this is the case in the Illinois, for it is here surpassed by several other species. Zimmer ('99) finds that this species is the most common winter rotifer in the plankton of the Oder, with a maximum in the spring and a predominance of var. *tecta* from July to September. Schörler ('00) finds it to be the most common rotifer in the Elbe—from April to November; and Skorikow ('97) finds it in the Udy, in Russia, throughout the summer in great numbers, but surpassed by *Synchæta*, *Polyarthra*, and *Brachionus angularis*. The variety *tecta* greatly exceeds var. *stipitata* in these waters. Seligo ('00) finds it throughout the year in Prussian lakes near Danzig, with a maximum in May. There are indications, in his data, of recurrent pulses during the summer, but his interval of collection is too great to follow their history. Burckhardt ('00a) finds it throughout the year in Swiss waters, with its single maximum in August. Jennings ('94, '96, and '00) reports it in the summer plankton of Lake Michigan and Lake Erie and of inland waters of Michigan.

*Anuræa hypelasma* Gosse.—Average number of females, 2,390; of eggs, 1,917. This species has a very definite limitation to a period extending from early in June to the first days of November. There are but two records outside of these limits—a single female and egg on Jan. 11, 1898, and another upon April 19 of the same year. The probabilities of occurrence in very small numbers at all temperatures is thus indicated. The following table gives the data of pulses and temperatures.

All of the pulses save one occur at temperatures above 70°, and with this exception the species declines rapidly and disappears shortly after temperatures pass below 60°. It is plainly, in our waters, a summer planktont, with its optimum temperature close to the summer maximum. This species takes no share in the vernal pulse, and there is no satisfactory evidence of any fluctuation corresponding to it at any other season. There are three or four pulses in each summer, and the species is apparently polycyclic, for winter eggs were found in 1898 either at the maximum of the pulse or the week or fortnight following. Thus 24,000 winter eggs were recorded on Sept. 27, 1898, the date of the maximum of the September pulse. The parthenogenetic eggs preponderate during the rise of the pulses in a very marked manner in this species. For example, in this September pulse 55,400 eggs were recorded during its rise to 500 during its decline. In like manner, in the case of the

PULSES OF ANURÆA HYPELASMA.

| Year | First record | | Pulses | | |
|---|---|---|---|---|---|
| | Date | Temp. | Date | Temp. | No. |
| 1896 .......................... | June 27 | 80° | June 27 | 80° | 1,200 |
| 1897 .......................... | June 28 | 75° | July 14 | 79° | 10,400 |
| 1898 .......................... | June 14 | 83° | June 21 | 77° | 9,600 |

| Year | Pulses | | | | | | Last record | |
|---|---|---|---|---|---|---|---|---|
| | Date | Temp. | No. | Date | Temp. | No. | Date | Temp. |
| 1896 | Aug. 15<br>" 29 | 81°<br>74° | 2,000<br>3,600 | ——— | ——— | ——— | Sept. 30 | 58° |
| 1897 | Aug. 31 | 80° | 20,000 | Oct. 5 | 71° | 23,200 | Nov. 2 | 55° |
| 1898 | Aug. 16 | 77° | 16,000 | Sept. 27<br>Oct. 18 | 73°<br>52° | 43,200<br>13,500 | Nov. 1 | 45° |

August pulse 15,200 eggs were found on the rise to 4,000 on the decline.

The location of the pulses of *A. hypelasma* is of special interest. It will be seen in Table I. that they occur in 1898 in the same collections in which the pulses of the other species of *Anuræa* and many other rotifers occur, or in collections but a week removed. They coincide in general with dates of the ploiman maxima noted in the opening discussion, and exhibit the same correlation with hydrographic conditions and intercalation with the pulses of chlorophyll-bearing organisms which were noted in the general discussion and have been found in preceding species. The comparison with *Anuræa* of the *cochlearis* group affords a curious instance of an entire suppression (Table I.) of one species of a genus (*cochlearis*) in the month of August and the occurrence of a normal pulse in another (*hypelasma*). Comparison of the distribution of *cochlearis* in previous summers would lead us to expect a *cochlearis* pulse in August, 1898, but none appears in this interval, while *hypelasma* runs a normal course of recurrent pulses throughout the summer. This August pulse of *hypelasma* (Table I.) culminates August 16, just a week after the symmetrical and well-defined pulse of chlorophyll-bearing organisms (Pl. II.) of August 9.

With a single exception, all of the pulses of 1896 and 1897, indicated in the table, fall a week later than, or coincide with, the pulses of chlorophyll-bearing organisms, as in 1898.

This species has not occupied a prominent place in the literature of fresh-water plankton. Weber ('98) finds it rare in Swiss waters in the summer. Lauterborn ('93) classes it with the monocyclic summer forms in the plankton of the Rhine, though he states in a footnote that he had found winter eggs once in June. It is probably polycyclic in our waters. Skorikow ('96) finds it in the summer plankton of the river Udy, in Russia, but it is not mentioned by other investigators of the potamoplankton of Europe. Apstein ('96) does not report it from Lake Plön.

*Asplanchna brightwellii* Gosse.—Average number, of adults 2,079, of eggs, 396; averages in 1897, 16,161 and 2,156. This is a polycyclic perennial planktont in our waters. It has been found in every month of the year, but the greater numbers and more continuous occurrences lie between May 1 and October 30. In 1898 (Table I.) all but 200 of the 108,120 recorded, lie within these limits, and all but 260 above 60°. In previous years approximately the same limits are found. The following table gives the data of pulses and temperatures.

Pulses of Asplanchna brightwellii.

| Year | Date | Temp. | No. | Date | Temp. | No. |
|---|---|---|---|---|---|---|
| 1894 | —— | —— | —— | —— | —— | —— |
| 1895 | —— | —— | —— | June 19 | 80° | 6,678 |
| 1896 | May 1 | 70° | 1,788 | June 27 | 80° | 1,600 |
| 1897 | —— | —— | —— | —— | —— | —— |
| 1898 | May 5 | 60° | 20,800 | June 21 | 77° | 1,100 |

Pulses of Asplanchna brightwellii—*Continued.*

| Year | Date | Temp. | No. | Date | Temp. | No. | Date | Temp. | No. |
|---|---|---|---|---|---|---|---|---|---|
| 1894 | July 30 | 82° | 19,398 | ——— | ——— | ——— | ——— | ——— | ——— |
| 1895 | July 29 | 75° | 1,344 | Aug. 12 | 79° | 118,206 | Nov. 14 | 45° | 1,725 |
| 1896 | ——— | ——— | ——— | Aug. 21 | 79° | 1,200 | ——— | ——— | ——— |
| 1897 | July 21 | 83° | 3,200 | Aug. 10 | 81° | 5,200 | Sept. 9 | 80° | 284,000 |
| 1898 | Aug. 2 | 79° | 23,200 | Aug. 23 | 81° | 4,000 | Sept. 27 | 73° | 6,400 |

It will be seen from this table that all the pulses save one, and that one (Nov. 14, 1895) poorly defined, lie between 60° and the maximum temperatures, indicating an optimum near the summer maximum. There is in this species no prominent vernal pulse such as that found in *Anuræa*, and the highest numbers were reached during the height of the warm season.

The evidence of the polycyclic character of the seasonal distribution of this species is shown in the following table, which gives the occurrences of ovigerous females, males, and winter eggs in 1898. It will be noted that ovigerous females are more numerous during the rise of the pulse; that the males appear just before, during, and after the culmination of the pulse; and that winter eggs are absent *only* during the rise of the pulse, and appear at or after its culmination and during the decline. The data given afford a fine illustration of the seasonal distribution of polycyclic rotifers, and of the relation of the sexual cycle to the number and character of the representatives of the species in the plankton. The growth of the pulse results from a rapid succession of parthenogenetic generations in the course of about two weeks, and it culminates with or shortly after a pulse in the food supply. The decrease in food supply is attended by the appearance of males and winter eggs, a decrease in ovigerous females, and a decline of the species. With the recurrence of the food supply the parthenogenetic cycle again begins. The same course of events is run in each recurrent pulse. Food supply rather than temperature seems to be the determining factor in this rhythm.

Asplanchna brightwellii.

| Date | Males | Females without eggs | Ovigerous females | Winter eggs |
|---|---|---|---|---|
| May 3 | 0 | 3,200 | 12,800 | 0 |
| " 10 | 8,000 | 4,800 | 8,000 | 1,600 |
| " 17 | 1,600 | 5,600 | 4,000 | 100 |
| " 24 | —— | 400 | 0 | 200 |
| " 31 | —— | 200 | 0 | 400 |
| June 7 | —— | 200 | 0 | 0 |
| " 14 | —— | 0 | 0 | 0 |
| " 21 | —— | 800 | 300 | 0 |
| " 28 | —— | 100 | 0 | 0 |
| July 5 | —— | 120 | 40 | 120 |
| " 12 | —— | 0 | 0 | —— |
| " 19 | —— | 40 | 240 | —— |
| " 26 | 240 | 12,400 | 5,260 | 60 |
| August 2 | 4,000 | 7,200 | 12,000 | 5,600 |
| " 9 | —— | 80 | 0 | 800 |
| " 16 | —— | 0 | 800 | 800 |
| " 23 | —— | 3,200 | 800 | 60 |
| " 30 | —— | 1,600 | 800 | 1,600 |
| September 6 | —— | 0 | 0 | 0 |
| " 13 | —— | 0 | 0 | 0 |
| " 20 | —— | 540 | 600 | 0 |
| " 27 | —— | 3,200 | 3,200 | 0 |
| October 4 | —— | 500 | 0 | 1,000 |
| " 11 | —— | 1,000 | 0 | 500 |

An examination of the location of the pulses of *Asplanchna brightwellii* shows (Table I.) that in 1898 one coincided with the pulse of chlorophyll-bearing organisms (Pl. II.) and the remaining four followed it either in a week or fortnight. In previous years two pulses coincide with and five follow those of chlorophyll-bearing organisms, and a single ill-defined one (Nov. 14, 1895) precedes.

This species is not wholly herbivorous in its feeding habits. *Codonella*, *Difflugia*, and even other rotifers such as *Brachionus* and *Anuræa*, are frequently seen in the digestive tract. Diatoms, even *Melosira* and *Peridiniidæ*, as well as *Pediastrum* and other algæ, are frequently taken as food. In one instance a *Daphnia cucullata* 300 $\mu$ in length was seen in the stomach in a transverse position. It was fully a third the length of the animal which had eaten it.

*Asplanchna brightwellii* is reported by Skorikow ('97) in the summer plankton of the Udy, in Russia; by Schorler ('00) as sporadic in the Elbe in June and September; and by Lauterborn ('93) from the Rhine, where its cycle coincides with that of *A. priodonta*. Zacharias ('98) reports it in German reservoirs in June and August. It is a cosmopolitan species, but does not seem to have been found by other plankton investigators in European waters.

*Asplanchna ebbesbornii* Huds.—Average number of adults in 1895, 942. In 1898, only winter eggs of the species were noted in the plankton in February, June, July, September, and October, though adults were doubtless there. Adults have doubtless occurred sporadically in all other years, and in 1895 reach a pulse of 21,518 on July 6 at 81°, which was followed by the appearance of males and winter eggs. All records of adults lie between April 29 and September 14 and above 60°. This rare rotifer has not appeared in the literature of fresh-water plankton elsewhere to my knowledge. Hempel's statement ('99) that his record of its occurrence in the Illinois is the first for this continent must be modified, since Leidy ('87) found it near Philadelphia. It is evidently a summer planktont in our waters, and the wide distribution of its winter eggs suggests that it, too, may be polycyclic; and their appearance in the plankton in large numbers with reference to the adults taken, leads to the further inference that its center of distribution is probably not in channel waters, and that it may be predominantly limicolous species, or have its center of distribution in the quieter backwaters.

*Asplanchna girodi* de Guerne is reported by Hempel ('99) in the backwaters in April.

*Asplanchna herricki* de Guerne.—Average number, 15; in 1897, 295; in 1896, 317. This species was always rather rare in our waters, and is apparently a summer planktont. The earliest record is April 29, at 64°, and the latest, November 15, at 48°. There is an indication of a vernal pulse in April–May in 1896 and 1897, and the recurrence of the species at intervals of a few weeks during the summer suggests a polycyclic habit similar to that of other members of the genus in our waters, but the data are insufficient to follow the cycles if such exist. Ovigerous females were present when numbers were greatest, and males and females with winter eggs were found at the time of the vernal pulse on May 25 (3,200) in 1897. Hempel's statement ('99) of its rarity in June and July is not borne out by the statistical records in these months in 1896, 1897, and 1898.

This rotifer is abundant in the summer plankton of Lake St. Clair, Lake Michigan, and lakes of northern Michigan (Jennings, '94 and '96), and it may be significant that it reaches its greatest development in the Illinois in the spring at 60°–70° and not during the period of maximum heat. This is about the summer temperature of those northern waters. This species has not to my knowledge appeared in the literature of European plankton, though it is found in European waters.

*Asplanchna priodonta* Gosse.—Average number, 441; winter eggs, 7. This species is much less abundant in our waters than its associate *A. brightwellii*, being outnumbered by it five to one in 1898. It is in the Illinois River a summer planktont only, at least so far as the records go, though reported elsewhere as perennial. The earliest record in any year is April 29, 1896, at 70°, and the latest October 5, 1897, at 70°, when an unusual pulse of 22,000 was found. The records are too scattered to trace the seasonal history. There are only indications of recurrent pulses. In May, 1898 (Table I.), the best-defined pulse is recorded. The details, which conform in the main to the sequence noted in *A. brightwellii* of ovigerous females with summer eggs during the rise, with males and winter eggs at and after the culmination of the pulse, are given in the appended table.

This is the only cycle found in this year. The presence of ovigerous females and winter eggs at other seasons as well, in other

ASPLANCHNA PRIODONTA.

| Date | Males | Females without eggs | Females with summer eggs | Females with winter eggs | Total individuals |
|---|---|---|---|---|---|
| May 10 | — | 3,200 | — | — | 3,200 |
| " 17 | 800 | 10,400 | 3,200 | — | 14,400 |
| " 24 | 120 | 1,600 | 200 | 200 | 2,120 |
| " 31 | — | 1,600 | 400 | — | 2,000 |

years, leads us to infer that the species may be polycyclic in our waters.

This limnetic rotifer figures largely in the fresh-water plankton of other localities, attaining a relative development greatly surpassing that thus far found in the Illinois River. Apstein ('96) reports it of irregular occurrence in the smaller lakes of Holstein, and Seligo ('00) finds it perennial in Prussian lakes, with maxima in April and September. Wesenberg-Lund ('00) also finds it perennial in Danish waters, with sexual cycles in May and September. Marsson ('00), in waters about Berlin finds a great variation in the seasonal occurrence, but the intervals of his collection—four to six weeks—were too great to follow seasonal distribution satisfactorily. Zacharias ('98b) finds it in the summer and autumn plankton in a number of German lakes and streams. Zimmer ('99) traces its appearance in the Oder from February to a maximum in May, from which time until the end of July it is "einer der häufigsten Planktonorganismen" (!). It then declines, but returns in small numbers in November. Schorler ('00) records it in the Elbe from April to October, with maxima in April–June and September. Burckhardt ('00a) finds, on the other hand, that in Swiss waters it reaches its greatest development from December to March with a maximum in January–February. There are also secondary maxima in May–June and in August. Lauterborn ('93) finds it to be a dicyclic perennial planktont in the Rhine, with maxima in April and September–October. A part of the great variation in the seasonal distribution of this species which is apparent in this survey of the literature may be due to insufficient collections or too great an interval between collections. The species is probably a polycyclic planktont with its greater pulses in spring and fall.

*Asplanchnopus myrmeleo* Ehrbg.—Taken in small numbers and irregularly from May to October at temperatures above 60°.

*Ascomorpha ecaudis* Perty.—Found rarely in early summer, in temperatures above 60°.

*Brachionus.*

The discussion of the species of this genus in our plankton is fraught with great difficulty. The genus is represented in the Illinois River by a very large number of individuals (fully 25 per cent. of the total *Ploima*), and the species are, almost without exception, exceedingly variable. They are loricate forms, and the variations affect the proportions of the lorica and the development of its prolongations in spines, antlers, and various diversifications of its surface. They are evident upon the most cursory examination in most cases, and have been utilized by systematists for the establishment of species. For example, Weber ('98) lists no less than 67 species of *Brachionus*, the most of which he regards as synonyms, and he includes only a part of the species. Fuller knowledge of the extreme variability in this genus has led the most thorough students of the rotifers to regard many of these so-called species as but varieties at the best, and to express their opinion with unmistakable plainness that descriptions of new species among rotifers should only be made after most careful determination of the variability of the organism (cf. Rousselet, '02, Jennings, '00, Wesenberg-Lund, '00, and Weber '98).

For one not a specialist in rotifers, the attacking of the *Brachionus* problem from the statistical standpoint is made difficult by the condition of the literature of the subject, owing largely to the semi-tropical distribution of the genus; by the absence of any critical monograph of the whole genus dealing fully with the synonymy of the subject; and by the necessity of establishing and maintaining constantly amid the ceaseless change of varying forms the same standards of distinction between the species or varieties into which *all* of the individuals enumerated must be assorted. Furthermore, these distinctions must be established before the plankton is counted; that is, before the limits of variation are fully appreciated. It is needless to say that my efforts are at best but approximations to a satisfactory analysis of the genus in our waters. *Brachionus* contains by virtue of variation in the hard parts of its lorica most excellent material for the study of the problem of variation, and its rapid multiplication makes possible a correlation with seasonal and environmental changes not often afforded.

Evidence has accumulated in the various papers of Schmarda, Ehrenberg, Barrois, v. Daday, Anderson, and others who have dealt with the microscopical fauna in tropical regions, that this genus attains its greatest development in the warmer waters. It is therefore not strange that Skorikow ('96) finds the genus well represented in the warm and shallow waters of Russia, and that the plankton of the Illinois River and its backwaters should contain a large and varied representation of the genus.

For convenience in treatment I have arranged the individuals of *Brachionus* under the following species, without, however, intending to indicate thereby that they have equal claims for specific recognition. The most of these include one or more varieties, and in designating the varieties I have taken those forms—for example, in *Brachionus bakeri*—whose descriptions most closely fit the predominant varieties in our waters, designating them often without complete consideration of all synonymic possibilities. In some cases several possible varieties have been included under one head. The following is the list of species with the varieties which have been thus separately enumerated.

*Brachionus angularis* Gosse,<br>
" " var. *bidens* Plate<br>
" *bakeri* Ehrbg.<br>
" " var. *bidentatus* Anderson<br>
" " " *brevispinus* Ehrbg.<br>
" " " *cluniorbicularis* Skorikow<br>
" " " *melhemi* Barrois and v. Daday<br>
" " " *obesus* " " "<br>
" " " *rhenanus* Lauterborn<br>
" " " *tuberculus* Turner<br>
" *budapestinensis* v. Daday<br>
" *militaris* Ehrbg.<br>
" *mollis* Hempel<br>
" *pala* Ehrbg.

*Brachionus pala* var. *amphiceros* Ehrbg.
" " " *dorcas* Gosse
" " " " forma *spinosus* Wierz.
" *quadratus* Rousselet
" *urceolaris* Ehrbg.
" " var. *rubens.* Ehrbg.
" " " *bursarius* Barrois and v. Daday
" *variabilis* Hempel

*Brachionus angularis* Gosse.—Average number of females, 57,890; of males, 25; of summer eggs carried, 29,560; of winter eggs, 1,223; of male eggs, 54. Of the individuals, 13,973 belong to var. *bidens* and 43,942 to the type; of the eggs, 2,035 belong to the variety and 28,802 to the type.

The combined statistics of the species will be discussed before the type and variety receive separate treatment. This species was found in every month of the year and throughout the whole range of temperatures, but the period of continuous presence and large numbers lies definitely between May 1 and November 1 and above 60°. In fact, in 1898, 98.6 per cent. of all the individuals were found between May 31 and October 4 and above 70°. Approximately the same conditions are found in previous years save in 1896, when an earlier spring (cf. Pl. X. and XII., Pt. I.) is attended by an earlier appearance of this species. Temperature seems thus to have a very decided effect upon the seasonal distribution of the species, and may have something to do with its apparent absence in the cooler waters of our Great Lakes and of L. St. Clair, for in spite of all the work done upon rotifers in those regions by Jennings it has been found but once—by Kellicott ('97) in a cove at Sandusky. This identification may be questionable, since he says "I at first took it for *B. mollis* Hempel." *Notops pelagicus*, since described by Jennings ('00), is found in the plankton of Lake Erie, and according to him this species is much like *B. mollis* in its appearance. In any event *B. angularis* is very abundant in our warm waters and practically absent in the more northerly waters of Michigan, whose summer temperatures are 10°–15° below that of the Illinois River and its backwaters.

*Brachionus angularis* presents the usual phenomenon of recurrent pulses, but in spite of the large numbers they are rather less regular than usual—for example, than those of *Anuræa* (Table I.). This irregularity is somewhat more pronounced in the separated records of the type and variety (Table I.) than in their combined statistics. This fact that their combined curve of occurrence is more regular than their separated curves constitutes, to my mind, evidence that we are dealing only with one genetic cycle, and that the variety does not belong to a fully separated genetic series.

The following table gives the data of pulses and temperatures in the several years.

PULSES OF BRACHIONUS ANGULARIS INCLUDING VAR. BIDENS.

| Year | Date | Temp. | No. | Date | Temp. | No. | Date | Temp. | No. |
|---|---|---|---|---|---|---|---|---|---|
| 1894 | ——— | —— | ——— | ——— | —— | ——— | July 13 | 82° | 12,118 |
| 1895 | ——— | —— | ——— | July 6 | 81° | 399,196 | July 23 | 80° | 100,826 |
| 1896 | May 25 | 70° | 67,600 | June 17 | 76° | 60,800 | July 10<br>" 23 | 80°<br>80° | 51,200<br>53,400 |
| 1897 | ——— | —— | ——— | June 28 | 75° | 75,000 | July 21 | 83° | 70,400 |
| 1898 | June 7 | 78° | 4,800 | June 28 | 78° | 544,000 | July 19 | 84° | 335,600 |
| Av'g | | | 36,200 | | | 269,776 | | | 103,924 |

| Year | Date | Temp. | No. | Date | Temp. | No. | Date | Temp. | No. |
|---|---|---|---|---|---|---|---|---|---|
| 1894 | ——— | —— | ——— | Sept. 17 | 73° | 1,272 | ——— | —— | ——— |
| 1895 | Aug. 12 | 80° | 585,090 | Aug. 29 | 80° | 105,735 | ——— | —— | ——— |
| 1896 | Aug. 8 | 85° | 20,800 | Aug. 21 | 79° | 29,600 | Sept. 16 | 71° | 5,051 |
| 1897 | Aug. 31 | 80° | 988,000 | Sept. 14 | 83° | 368,800 | Oct. 5 | 71° | 18,400 |
| 1898 | Aug. 16 | 77° | 353,600 | Sept. 6<br>" 27 | 79°<br>73° | 163,200<br>494,400 | Oct. 25 | 48° | 11,500 |
| Av'g | | | 486,872 | | | 195,834 | | | 11,650 |

It will be noted that all the pulses with one exception lie above 70°, averaging in fact 78.25°, indicating an optimum temperature near the summer maximum. The location of the pulses with respect to those of the chlorophyll-bearing organisms (Pl. II.) shows in the main the same relation that has been observed in other ploiman rotifers. In 1895, three *angularis* pulses lie in the period common to both, one of these coinciding in location and two following at the next collection. In 1896, two coincide and five follow at the next collection or shortly thereafter. In 1897, four follow at an interval of a week or a fortnight, and one is located where data are incomplete. In 1898, three coincide and three follow at a short interval, and one (June 7), a minor and ill-defined pulse, appears to lie on the rise of the pulse of the chlorophyll-bearing organisms. In the main the dependence of these rotifer pulses upon the recurrent periods of increase in these primal links in the food cycle is suggested by this coincidence or sequence. The pulses of *Brachionus angularis* coincide in the main with those of the totals of ploiman rotifers (Table I.).

There is no vernal pulse in the species at the time of the April–May volumetric maximum, and no large autumnal pulse. The pulses in August–September, at the close of our period of maximum heat, average much greater than those of other months, and still further indicate the relation of this species to the higher temperatures.

The eggs are carried by the female attached to the posterior end of the lorica. Usually but a single summer egg is carried at one time, but often two, three, and even four, have been seen during the height of the period of rapid reproduction. The relation of the number of eggs to the pulses is obscured in this species to some extent by the fact that the eggs are similar to those of other *Brachionus* and when detached cannot be identified with certainty. Records are therefore based upon attached eggs only. The number of these depends to some extent on the detachment in the processes of collection, killing, and subsequent handling. In a few cases detached male or winter eggs could be identified with some degree of probability by the constitution of the rotiferan plankton. An examination of the records of eggs (Table I.) will, however, suffice to indicate the prevalence of rapid reproduction during the rise of the pulses and the decline in the process during the fall of the pulse. Males, male eggs, and winter eggs were recorded in a number of instances at the culmination or during the decline of a pulse. For example, in 1898, they followed the pulses of August 16, September

6, and especially that of September 27, when they were found continuously for a month.

The separate records of the type and the variety (Table I.) contain in their seasonal distribution one point of special interest; namely, the appearance of the variety *after* the type has been present for some time. An examination of the records in the several years reveals the fact that var. *bidens* is practically confined so far as large numbers are concerned to the months of July–September. This appears in 1898 (Table I.) and is equally evident in 1896 and 1897, but is less noticeable in 1895. The first large pulse is passed in each year before var. *bidens* takes any appreciable part in the genesis of the pulses. Even the second large pulse is not extensively contributed to by the variety in some instances. On the other hand, the later pulses in 1895 and 1897 were mainly of the variety. There is thus in this species some evidence of *a tendency on the part of the variety marked by the development of a pair of posterior spines to appear in the latter part of the period of seasonal occurrence.*

The variety *bidens* in our records includes individuals with well-developed spines (*B. caudatus* Barrois and v. Daday), but they are not to my mind worthy even of varietal distinction, since they intergrade so completely with var. *bidens* and are merely well-developed examples of this variety, and I see no reason for giving the variety two names.

Wesenberg-Lund ('00) has expressed the opinion that the elongation of structural processes which he has noted in summer planktonts is an adaptation on their part to the changes in the buoyancy of the water dependent upon changes in its specific gravity and, as shown by Ostwald ('03 and '03a), in its molecular friction caused by seasonal fluctuations in temperature. It would seem that this tendency on the part of the spinous form of *Brachionus angularis* to appear in greater proportions in late summer at the period of maximum heat in our waters might be an illustration of Lund's thesis and Ostwald's theoretical considerations. The changes in temperature during the occurrence of the species are, however, not very great, though our incomplete records suggest (Pt. I., Table III. and Pl. X.—XII.) that August temperatures are higher on an average than those of July. The averages for June, July, and August are 77.75°, 81.03°, and 81.49°. In 1897, the dominance of the spinous type extends well into September, but it accompanies a period of summer heat (Pt. I., Pl. XI.) prolonged for a fortnight into September, with river water at or above 80°. In 1898, it falls away in numbers more rapidly than the spineless form (Table I.) as temperatures fall in October, though this tendency is less marked in previous years.

*Brachionus angularis*, as above stated, seems to be rare in the plankton of our more northerly and cooler American waters. It is also conspicuously absent from plankton of Swiss waters, as reported by Weber ('98) and Burckhardt ('00 and '00a), and from German lakes examined by Apstein ('96), Zacharias ('98), and Seligo ('00), and from Finland waters examined by Stenroos ('98). It was, however, found by Wesenberg-Lund ('98) in Danish waters, and in the Udy River, in Russia, by Skorikow ('97), whose statistical records show it to be the most abundant *Brachionus* in that stream, and outnumbered among the rotifers only by *Synchæta stylata* and *Polyarthra*. Schorler ('00) finds it in the Elbe from April to July and most abundantly in June. Lauterborn ('98) reports it as perennial in the Rhine and polycyclic, with winter eggs in April, June, August, October, and November. This distribution is much like that in the Illinois River, and will probably be found in temperate waters wherever the seasonal cycle is thoroughly examined.

*Brachionus bakeri* Ehrbg.—Average number of females, including all varieties, 594; eggs, 420. The following table, giving the average of each of the varieties in the several years, will serve to indicate their relative abundance, the totals showing the relative abundance of the *bakeri* group in each year and of each variety in the total of all the collections.

Though the species is greatly diversified by variation the number of individuals is much less than that of many other plankton rotifers in which variation is much less apparent.

It will be noted that the species was apparently more abundant in the earlier years. This is only in part the result of the distribution of the collections, as is shown by the fact that the numbers taken were much larger. Thus in 1898 the largest record is 7,600; in 1897 there are three occurrences in excess of this; in 1896, two; in 1895, three; and in 1894, four. The largest occurrence, 122,958, was on June 30, 1894. The largest numbers by far were recorded in 1894, a year of low water in spring. The hydrographic conditions of the following year were somewhat similar, but the development of *B. bakeri* was much reduced, at least at the time of the collections.

BRACHIONUS BAKERI.

| Year | No. of collections | Varieties | | | | Average Number per Collection | | | | | | | | | | Total individuals | Total eggs |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | *obesus* | | *cluniorbicularis* | | *rhenanus* | | *brevispinus* | | *bakeri* type | | *melhemi* | | *tuberculus* | | | |
| | | ♀ | eggs | ♀ | eggs | ♀ | eggs | ♀ | eggs | ♀ | eggs | ♀ | eggs | ♀ | eggs | | |
| 1894 | 10 | 0 | 0 | 9,273 | 4,873 | 4,656 | 4,977 | 19 | 19 | 169 | 63 | 3,529 | 1,874 | 10,040 | 6,169 | 27,677 | 17,978 |
| 1895 | 31 | 0 | 0 | 800 | 126 | 261 | 146 | 26 | 2 | 257 | 40 | 57 | 41 | 1,105 | 266 | 2,408 | 630 |
| 1896 | 43 | 18 | 0 | 447 | 327 | 140 | 64 | 365 | 255 | 79 | 70 | 292 | 106 | 616 | 229 | 1,957 | 1,051 |
| 1897 | 30 | 134 | 241 | 1,076 | 540 | 102 | 156 | 228 | 86 | 69 | 0 | 218 | 41 | 367 | 66 | 2,193 | 1,142 |
| 1898 | 52 | 41 | 62 | 90 | 95 | 118 | 138 | 139 | 15 | 2 | 0 | 49 | 49 | 155 | 42 | 594 | 420 |
| Total | 166 | 193 | 303 | 11,686 | 5,961 | 5,277 | 5,481 | 777 | 377 | 576 | 173 | 4,145 | 2,111 | 12,283 | 6,772 | 34,829 | 21,221 |

The reducing effect of the recurrent floods of 1896 may be traced in the smaller numbers recorded in this year; and the larger numbers of 1897 may be referred to the more stable conditions then prevailing. The very small numbers of 1898 may also be due to disturbed hydrographic conditions of that year. The number is much smaller than in 1896, when the hydrograph was even more disturbed, but in this latter year there was more run-off of impounded backwaters during the occurrence of *B. bakeri*,and this would tend to favor their appearance in channel waters.

The occurrences and numbers of this species (as a whole) are everywhere somewhat irregular, so that pulses of occurrence are somewhat ill defined. Several such pulses are indicated in 1898, and others recur in the records of previous years. As suggested by the data of 1898 (Table I.), the several varieties share in these pulses. The evidence upon this point is much more striking in other years, when numbers are larger. For example, in the following table note the pulse of 26,800 on August 23, 1897.

| Date | *obesus* | *cluniorbicularis* | *rhenanus* | *brevispinus* | *melhemi* | *tuberculus* | Total |
|---|---|---|---|---|---|---|---|
| Aug. 10....... | 0 | 0 | 0 | 0 | 0 | 200 | 200 |
| " 18....... | 0 | 1,200 | 200 | 600 | 2,000 | 5,200 | 7,400 |
| " 23....... | 0 | 7,800 | 1,800 | 3,400 | 2,200 | 11,600 | 26,800 |
| " 28....... | 0 | 200 | 400 | 200 | 0 | 1,000 | 1,800 |

In their location these pulses exhibit as a rule the same relation of coincidence or sequence to the pulses of chlorophyll-bearing organisms noted in some other species, and they frequently coincide with those of other *Ploima*, but not always.

This is perhaps the most variable of the rotifers of the plankton. At least its variations affect the fixed processes of the lorica and are thus quickly and easily appreciated. The species, in common with

*B. pala*, *B. angularis*, and probably *B. urceolaris*, has a variety—in fact, several varieties—with two posterior spines which are usually symmetrically placed but not always symmetrically developed. The form without posterior spines (var. *cluniorbicularis* Skorikow) intergrades with these, and a series might be formed with complete intergradations linking this in turn with var. *rhenanus* Lauterborn, in which the spines are but slightly and often unequally developed. From this we pass, by a slight elongation of the posterior spines, to var. *brevispinus* Ehrbg., thence to the type in which the spines as figured by Rousselet ('97) are directed posteriorly with but slight curvature. From this we may pass toward variants in which the symmetry is preserved, but the spines are much elongated and curved outwardly. The anterior spines in such individuals are also more elongated and exhibit a similar outward curvature (var. *melhemi* Barrois and v. Daday). Extreme types of this curvature sometimes occur (*B. falcatus* Zach.). In another direction we find the bilateral symmetry of the processes, both anterior and posterior, to some extent lost as a result of differences in the curvature of the spines (var. *tuberculus* Turner). There are also differences in the surface markings of the lorica which have been utilized as specific distinctions. Kertész ('94) describes as *B. granulatus* a species with a minutely pustulate surface, and Turner's *B. tuberculus* takes its name from this same feature. It seems questionable, however, if these surface markings are even of varietal value. Individuals without spines, in which the transverse diameter is relatively large (var. *obesus* Barrois and v. Daday), are also found.

In assorting the individuals belonging to this variable group I have arranged them under the following heads: *bakeri* O. F. Müll., *bidentata* Anderson (non *bidentatus* Kertész), *brevispinus* Ehrbg., *cluniorbicularis* Skor., *melhemi* Barrois and v. Daday, *obesus* Barrois and v. Daday, *rhenanus* Lauterborn, and *tuberculus* Turner. The number might have been increased. The individuals referred to var. *melhemi* include many if not all of the long-spined specimens such as Rousselet ('97) has referred to the type, the latter designation having been given to individuals intermediate between this and *brevispinus*. The variety *tuberculus* includes the asymmetrical individuals, regardless of the surface markings. I will now briefly compare the seasonal distribution of these varieties and note any peculiarities which mark them individually:—

*Brachionus bakeri* O. F. Müll., type form.—Average number, 2. As shown in table on p. 193 (MS.), this form is much more abundant in previous years though it is relatively rare, ranking sixth in the list of seven forms recognized. The most of the records fall prior to the middle of August, and it seems to be an early rather than a late summer form.

*Brachionus bakeri* var. *obesus* Barrois and v. Daday.—Average number of females, 41; of eggs, 62. The proportion of egg-bearing to non-egg-bearing females—2 to 3 in all records—is larger than in any other variety. It seems probable that the lateral expansion which marks this variety may be only the result of rapid reproduction. In common with most of the other varieties this one occurs at the time of the pulses, but it is last in the list of seven, and the numbers are too small to trace its seasonal preferences with certainty.

*Brachionus bakeri* var. *bidentatus* Anderson (*non* Kertész).—Found once—August 5, 1895, at 78°.

*Brachionus bakeri* var. *cluniorbicularis* Skor.—Average number of females, 90; of eggs, 95. This also was more abundant in all previous years. This variety is, next to *tuberculus*, the most abundant of the varieties in our plankton. The two stand at opposite extremes of the series of varieties, the former being least modified, and the latter most, especially in the direction of asymmetry. It includes about one third of all the individuals of the species. The ratio in the grand total of females to eggs carried—11,708 to 5,976—is somewhat less than the average in the entire species. This variety is distributed throughout the whole seasonal range of the species with no marked predominance in any particular part of it. It is wholly absent in the early summer of 1897, but very abundant in late summer of that year, though not in other years. The autumn of 1897 was one of long-continued high temperatures (Pt. I., Pl. XI.), and under those conditions this variety constituted two thirds of the individuals belonging to the species. If we add to it the representatives of *rhenanus*, *obesus*, and *brevispinus* we have a total of 15,400 individuals with no posterior spines, or with spines but slightly developed, in contrast with only 2,200 with such well-developed spines referred to varieties *melhemi* and *tuberculus*. The conditions of temperature were those in which according to the hypothesis of Wesenberg-Lund ('00) we should expect a predominance of the long-spined forms.

*Brachionus bakeri* var. *rhenanus* Laut.—Average number of females, 118; of eggs, 138; but more abundant in previous years. This is the third in numbers on the list of seven varieties, being surpassed only by *cluniorbicularis* and *tuberculus*. It includes about one sixth of the individuals referred to this species. It is found throughout the whole range of the seasonal distribution of the species and exhibits the same peculiarities noted in *cluniorbicularis*, to which it is very closely related. The proportion of females to eggs noted in this variety is very large; 5,284 to 5,485 in the grand total.

*Brachionus bakeri* var. *brevispinus* Ehrbg.—Average number of females, 795; of eggs, 390; but somewhat more abundant in previous years. It was found throughout the whole seasonal range of the species, but not quite so abundantly in the latter as in the earlier half of the summer, resembling in this particular the type. The number of eggs carried in this species is in relation to the number of females less than usual—3,906 to 795.

*Brachionus bakeri* var. *melhemi* Barrois and v. Daday.—Average number of females, 49; of eggs, 49. More abundant in previous years, especially in 1894, when it constituted over a fifth of the individuals (25,764) in the largest pulse recorded for the species as a whole—122,958 on July 30. In the aggregate in all years it includes only about a ninth of the individuals referred to the species. This form was originally described from Syria, but it is found in great perfection in our plankton, even in the extreme type described by Zacharias ('98b) as *B. falcatus*. It occurs throughout the whole seasonal range of the species, its distribution being somewhat similar to that of *tuberculus*. I do not find any constant tendency limiting its occurrence to any part of the seasonal range.

*Brachionus bakeri* var. *tuberculus* Turner.—Average number of females, 155; of eggs, 42; but very much more abundant in previous years, especially in 1894, when it constituted almost half (55,332) of the largest pulse of the species (122,958). This, the most divergent of all the varieties, constitutes over a third of all the individuals referred to the species. It occurs throughout the whole seasonal range of the species, though the larger numbers were found in 1894–97 in the *earlier part or middle of* the summer. I find nothing in a comparison of the seasonal distribution *of these more decidedly spinous varieties of B. bakeri* with that of the smoother forms, such as *cluniorbicularis*, which indicates any correlation with temperature conditions of a nature to support Wesenberg-Lund's suggestion that the elongation of the processes of plankton organisms arises in response to the lessened buoyancy of the water during higher temperatures. Forms with and without such processes are found among the varieties of this species, and both occur indiscriminately throughout the whole range of seasonal occurrence, and, so far as I can see, *the statistical data of their distribution* with respect to temperature afford no evidence of a correlation of spinosity and high temperatures in this species. Other factors doubtless enter into this problem and obscure this response if it exists.

*B. bakeri* is everywhere widely distributed in fresh water. Its occurrence in the plankton of open waters has not, however, been a matter of frequent note. In fact there is some reason to think that it is largely confined to shallow warm waters where vegetation is close at hand, or where at least the flagellates and smaller algæ abound, as they do in water fertilized by decaying vegetation or other organic matter. There is, it seems, no reason for regarding this species as merely adventitious in our plankton. It bears all the characteristics of a true limnetic organism in our environment. Its presence in the plankton is not due to floods or other disturbances which might carry it from a littoral region into the open water. It exhibits characteristic pulses, and is found everywhere in summer in company with typical planktonts in open water.

Zacharias ('98) records it in some German ponds and streams, and Weber ('98) in Swiss marshes in the warmer months. Stenroos ('98) also finds it in the summer plankton of littoral and open waters in the shallow Nurmijärvi Lake in Finland. Jennings ('00) reports it as one of the commonest rotifers in East Harbor, Lake Erie, and in the swamps on the islands. In land-locked pools short-spined varieties were found, and in swamps the long-spined. Speaking of this difference, Jennings says "Possibly the different form found in these pools is due to the greater concentration of various salts in this water or to some kindred factor." In our own region both varieties occur at the same time in the same environments, channel and backwaters alike, and such factors as Jennings suggests to explain the appearance of the varieties cannot well be operative here in channel waters. Schorler ('00) reports the species as sporadic in the Elbe, and Skorikow ('97) finds both *B. bakeri* and its variety *brevispinus* sparingly in the Udy in summer months.

This species in common with other *Brachionidæ* was infested by *Bimœrium hyalinum* Przesm., and occasionally by a filamentous fungus-like growth. Empty loricæ were wont to appear with the culmination of a pulse and subsequently. No males were identified as belonging to this species, and attached male eggs were recorded only late in September, 1897, at the close of an unusual pulse. They were found on var. *cluniorbicularis* and *rhenanus*. Females with winter eggs were not at any time recorded for this species. It may be that some of the free winter eggs referred to the genus *Brachionus* (Table I.) belong to this species. The recurrent pulses are similar to those of known polycyclic species, and we may infer the probability of such a phenomenon in *B. bakeri*, though conclusive proof of its occurrence is not found in the statistical records.

*Brachionus budapestinensis* v. Daday.—Average number of females, 4,211; of eggs (carried), 740. This is one of the most sharply defined species of *Brachionus* and a typical planktont of open waters. It has, moreover, a sharply limited seasonal distribution in which it is apparently polycyclic. The appended table gives the dates and temperatures of appearance and disappearance and the pulses in the several years.

In the main, the period of occurrence is practically from the end of June till the early part of October and above 60°. A record in May, 1896, and an isolated one in December of the same year, indicate an extension of this period, but such occurrences are rare and irregular and the numbers small. This abrupt decline in 1898 as temperatures pass 60° (Pl. XII., Pt. I., and Table I.) is paralleled in previous years. The normal seasonal routine seems to be as follows: The species reappears in the plankton in May–June at 70°, rising slowly to its first pulse (average, 26,104) in July, with a larger pulse (average, 184,453) in the following month during the maximum heat, and a much smaller one (average, 10,044) in September, followed immediately by an abrupt decline. The average temperature of the larger pulses lies close to the season's maximum, while the latest pulse at the lower temperature (72.2°) averages but 10,044. These data all indicate that this is a midsummer planktont, with its optimum temperature near the summer's maximum. The

PULSES OF BRACHIONUS BUDAPESTINENSIS.

| Year | First Record | | Pulses | | | | | | | | | Last Record | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Date | Temp. | Date | Temp. | No. | Date | Temp. | No. | Date | Temp. | No. | Date | Temp. |
| 1894 | June 29 | 83° | June 29 | 83° | 292 | ——— | ——— | ——— | Sept. 4 | 78° | 700 | Sept. 17 | 72° |
| 1895 | June 19 | 80° | July 18<br>Aug. 1 | 80°<br>78° | 3,816<br>13,716 | Aug. 21 | 82° | 48,667 | Sept. 20 | 78° | 4,563 | Sept. 27<br>Oct. 23 | 73°<br>51° |
| 1896* | May 8<br>June 1 | 74°<br>72° | July 2 | 81° | 16,000 | July 23 | 78° | 52,000 | Aug. 26<br>Sept. 30 | 76°<br>58° | 4,000<br>1,400 | Sept. 30<br>Dec. 3 | 58°<br>32° |
| 1897 | July 14 | 78° | July 30 | 84° | 37,200 | Aug. 24<br>Sept. 7 | 77°<br>80° | 249,600<br>552,000 | Oct. 5 | 70° | 4,800 | Oct. 12 | 65° |
| 1898 | June 28 | 78° | July 19 | 84° | 85,600 | Aug. 16 | 77° | 20,000 | Sept. 27 | 73° | 44,800 | Oct. 18 | 52° |
| Average | | 77.5° | | 81.6° | 26,104 | | 78.8° | 184,453 | | 72.2° | 10,044 | | 61.8°† |

†Omitting Dec. 3, 1896.

relation of hydrographic conditions to the relative development of pulses in different years is seen on a comparison of the record for 1896 and 1897, the former (Pt. I., Pl. X.) being a year of recurrent floods and the latter (Pt. I., Pl. XI.) one of stable conditions through the greater part of the seasonal distribution of the species in question. The average numbers in these two years were 3,105 and 31,306, respectively, and the average amplitude of the pulses 18,250 and 97,200, showing, respectively, a ten- or five-fold increase in the latter year. The extension of the heated term into September in 1897, is reflected in the large September pulse (552,000) and in the extension of the period of occurrence into October.

The locations of the pulses of *Brachionus budapestinensis* in 1898 correspond with those of the *Ploima* in general. They likewise coincide with or follow those of the chlorophyll-bearing organisms (cf. Pl. I. and II. with III. and IV. and Table I.). Similar relations are apparent in 1896 and 1897 but are less evident in prior years. They suggest an interrelationship of the pulses in this species with the fluctuations in the food supply.

Males, male eggs, and winter eggs were not recorded, but the recurrent pulses in this species are so similar to those in other rotifers in which the evidence of the occurrence of sexual reproduction at the culmination of each pulse has been found, that the inference may be made that this species likewise is polycyclic in our waters. Females carrying one or two summer eggs have been found in greatest abundance during the rise of the pulse, and only in small numbers, if at all, during its decline.

This species is subject to some variation in the development of surface ornamentation, in the ratio of width and length, and in the curvature of the median spines. It is usually somewhat more slender than figured originally by v. Daday ('85) or even by Hempel ('96), who described a form somewhat more slender than that figured by v. Daday, as *B. punctatus*. Shortly afterwards Skorikow ('96) described the same species as *B. lineatus* from Russian waters. The name given by v. Daday has priority, and as neither the Russian nor the American forms are to my mind well enough set off to merit even varietal distinction, I have used the name given by v. Daday, and have included under it both wide and narrow forms and those with incurved or outcurved median spines. The fact that their common record of seasonal distribution forms a seasonal curve of typical character is corroborative of the view, though not conclusive, that we are dealing with a single species and not with several.

This species has not been widely reported in the fresh-water plankton. It is evidently a planktont of warmer waters, and for that reason may have escaped notice, since the cooler waters have been the more thoroughly explored. Thus it was not found by Weber ('98) in Swiss waters in his thorough explorations about Geneva, nor by Jennings ('94, '96, '00) in the Great Lakes or inland waters of Michigan. It has, however, been recorded by Skorikow ('97) in the plankton of the Udy River, in Russia, where it was exceeded in number by only two species of its genus, *B. pala* and *B. angularis*, ranking tenth in numbers among all the rotifers. His data of frequency from July to October suggest several recurrent pulses. It has likewise been found by Lauterborn ('98) in the plankton of the Rhine, where he classes it with the stenothermal planktonts. Zacharias ('98) finds it in ponds near Leipzig, and it was originally described by v. Daday ('85) from Hungarian waters, and again noted there by Kertész ('94). Fuller exploration of the summer plankton in warmer regions will doubtless extend the record of its range.

*Brachionus militaris* Ehrbg.—Average number of females, 147; of eggs (carried), 98. In previous years the species was much more abundant, the averages in 1897 being 1,412 females and 523 eggs, and in 1896, 1,288 females and 576 eggs. This greater development in years prior to 1898 is evident in many of the *Brachionidæ*.

The following table gives the dates of first and last records in each season, and the location, temperature, and amplitude of the pulses in the several years.

This is evidently a summer planktont with well-defined limits. These limits appear much less evident in 1898 (Table I.) than in prior years. In 1896 and 1897, for example, the species is almost continuously present in the plankton from the time of its first appearance until the last record for the season. All of the records save two lie above 70°, and the average temperatures at which the pulses occur are all at or above 80°. Its optimum thus lies near the summer maximum. The lower limits are not definitely established owing to insufficient collections in periods of rise and decline, but they seem to lie near 70°, with small numbers lingering to 60°.

PULSES OF BRACHIONUS MILITARIS.

| Year | First Record | | Pulses | | | | | | | | | Last Record | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Date | Temp. | Date | Temp. | No. | Date | Temp. | No. | Date | Temp. | No. | Date | Temp. |
| 1894 | June 12 | 78° | July 13 | 82° | 5,110 | | | | Sept. 4 | 78° | 4,725 | Sept. 4 | 78° |
| 1895 | July 23 | 80° | —— | —— | —— | Aug. 1<br>" 12 | 78°<br>79° | 1,524<br>5,940 | Sept. 12 | 81° | 1,460 | Sept. 20 | 79° |
| 1896 | June 11 | 73° | July 2<br>" 23 | 80°<br>83° | 3,200<br>18,000 | Aug. 15 | 82° | 7,200 | —— | —— | —— | Sept. 30 | 58° |
| 1897 | July 14 | 78° | July 14 | 78° | 24,000 | Aug. 10 | 81° | 4,800 | Aug. 31 | 80° | 4,000 | Sept. 21<br>Oct. 26 | 71°<br>60° |
| 1898 | May 24 | 74° | July 12 | 78° | 120 | —— | —— | —— | Aug. 30 | 82° | 3,200 | Sept. 27 | 73° |

This species has never developed large pulses in the channel waters of the Illinois. Hempel's statement ('99) that it is "the most abundant species of the genus" can apply only to certain collections in vegetation-rich backwaters, for in the river it is surpassed in the totals of occurrences in the statistical records by eight other forms of *Brachionus*, namely, *variabilis*, *pala*, *amphiceros*, *dorcas*, *rubens*, *budapestinensis*, *cluniorbicularis*, and *tuberculus*. I found it in very great abundance in the July–August plankton of Crystal Lake, a shallow warm pond rich in vegetation, formed by damming a small creek tributary to the Wabash system, near Urbana, Ill. From the relatively small numbers, the slight amplitude of the pulses, and their somewhat irregular development I am inclined to think that the centers of distribution of this species are not in the open water of the river and its backwaters, but more in the vegetation of warm, shallow regions such as the margins of our bottom-land lakes. It is thus to some extent adventitious in our plankton.

The pulses of this species are relatively so small that they do not contribute an appreciable amount to the total ploiman pulses, nor do more than 50 per cent. of their number coincide with such general pulses, though they are sometimes found during their rise. The greater part of them coincide with the pulses of chlorophyll-bearing organisms (Pl. I. and II.), suggesting a food relationship.

This species is one of the best-defined in the genus, though in the character of its asymmetry it varies toward *B. bakeri* var. *tuberculus* Turner. It exhibits some variation in the degree of asymmetry, in the curvature of the spines, and in the surface markings. The indications of pulses suggest a polycyclic habit, but no evidence in the way of males, male eggs, or winter eggs was recorded which will substantiate the inference. A female carrying a winter egg was found Sept. 21, 1897, at the close of the period of occurrence. Females with one, two, or three summer eggs were found throughout the summer and in somewhat larger numbers during the rise of the pulses.

*Brachionus mollis* Hempel.—Average number of females, 137; of eggs, 10. More abundant in previous years, the average in 1897 being 1,092 and 277, and in 1896, 428 and 56.

This likewise is a summer planktont. The earliest record of its appearance in the plankton is June 17, 1896, at 76°; and the latest, October 17, 1894, at 58°. With but two exceptions the species was taken only above 70°, and the period of most continuous occurrence and largest numbers is near the summer maximum of 80°. The optimum is thus near the summer maximum. This species was never taken in the plankton in large numbers, the greatest being on Sept. 14, 1897 (20,000), at 84°. On account of the small numbers and somewhat irregular occurrences the phenomenon of recurrent pulses is here less apparent than it is in more abundant species. The appended table records the best-defined ones. These pulses share in the general ploiman pulses in only about 50 per cent. of the cases, and the most of them coincide with or follow shortly after the pulses of chlorophyll-bearing organisms.

PULSES OF BRACHIONUS MOLLIS

| Year | Date | Temp. | No. | Date | Temp. | No. |
|---|---|---|---|---|---|---|
| 1895.... | July 6 | 81° | 742 | Sept. 5 | 75° | 954 |
| 1896.... | July 18 | 79° | 1,200 | Aug. 21 | 79° | 8,400 |
| 1897.... | July 30 | 85° | 11,600 | Sept. 7 | 80° | 20,000 |
| 1898.... | Aug. 23 | 81° | 800 | Sept. 27 | 73° | 4,800 |

So far as I am aware this species has not been found in other waters than the Illinois River and its adjacent backwaters. Hempel ('99) reports it as most abundant in the marshy environment of Flag Lake.

*Brachionus pala* Ehrbg.—Average number, including all varieties: females, 19,969; eggs, 25,974. The following table gives the average number, in the several years, of the varieties here included, and it will serve to show their relative frequency.

This is the most abundant species of the genus in our waters, the grand total of all occurrences exceeding 9,000,000. As a whole the species was much more abundant in the stable year 1897 (180,998), and less abundant, all things considered, in the disturbed conditions of 1896 (36,665). As a whole the type form *pala* is less abundant than *amphiceros*. It forms but 28 per cent. of the total, as compared with 68 per cent. included in the latter variety. *Dorcas* forms less

Brachionus pala and Varieties. Average Number per Collection.

| Year | No. of collections | *pala* | | *amphiceros* | | *dorcas* | | *spinosus* | | Total individuals | Total eggs |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ♀ | Eggs | ♀ | Eggs | ♀ | Eggs | ♀ | Eggs | | |
| 1894 | 10 | 1,750 | 478 | 159 | 32 | 4 | 0 | 0 | 0 | 1,913 | 510 |
| 1895 | 31 | 28,073 | 22,822 | 15,869 | 11,069 | 1,280 | 1,025 | 106 | 12 | 45,328 | 34,928 |
| 1896 | 43 | 22,625 | 4,453 | 5,430 | 715 | 6,216 | 2,309 | 2,384 | 21 | 36,655 | 7,498 |
| 1897 | 30 | 24,475 | 32,544 | 156,296 | 35,625 | 121 | 0 | 106 | 40 | 180,998 | 68,209 |
| 1898 | 52 | 2,693 | 20,809 | 17,071 | 5,103 | 170 | 74 | 33 | 2 | 19,967 | 25,988 |
| Total... | 166 | 79,616 | 81,106 | 194,825 | 52,544 | 7,791 | 3,408 | 2,629 | 75 | 284,861 | 137,133 |

than 2 per cent; and the form *spinosus*, less than 1 per cent. The proportions formed by the several varieties fluctuate from year to year and from season to season,—indeed, from collection to collection (Table I.). Thus in the first three years *pala* exceeded *amphiceros*, while in the last two these conditions were reversed; and in 1896 the form *spinosus* contributes 6.5 per cent. of the individuals. The predominance of the *pala-amphiceros* group is, however, preserved throughout all of the years.

The species as a whole is found throughout the entire seasonal range of temperatures but with very great fluctuations in numbers. Speaking generally, there are vernal and autumnal pulses separated by a midwinter minimum which is well sustained, developments in excess of 5,000 per $m^3$ being very rare in this season. There is also a midsummer minimum more or less diversified by pulses of some magnitude. This sequence was not fully realized in any single year of our records, but this may be due in part to insufficient collections at times of the major pulses. Thus in 1894 only a small autumnal pulse (13,650) was detected. In 1895, there was a small vernal pulse (67,338), and a belated autumnal pulse (320,915) lasting a full month in November–December. In 1896, there was a very abrupt vernal pulse rising from 53,618 on April 17 to 1,012,350 on April 24, while in the fortnightly fall collections the only pulse detected was one of 14,000. In 1897, the monthly collections of the spring seem to have missed all considerable developments, the largest recorded being only 16,000. On August 31 and October 12 of that year, however, there were pulses of 1,398,000 and 1,605,600. In 1898 there was a well-developed vernal pulse of 451,200 and a small autumnal one of 83,200.

The species is not, however, dicyclic, for both the winter and summer interims are marked by occasional recurrent pulses of smaller proportions. The table on the next page shows the locations and temperatures of the culminations of these pulses.

From this table it is evident that a wide range of optimum temperatures is possible. Nevertheless, 23 of the 31 pulses occur above 50°, and 21 of them above 60°. In 1898 only 3 per cent. of the individuals are found below 57°, and with the exception of 1895 approximately these conditions will be found in the other years. *Brachionus pala* is thus a perennial planktont, but as a rule it reaches its largest developments only above 60° in our channel waters.

PULSES OF BRACHIONUS PALA AND VARIETIES.

| Year | Date | Temp. | No. | Date | Temp. | No. | Date | Temp. | No. |
|---|---|---|---|---|---|---|---|---|---|
| 1894 | ——— | —— | ——— | ——— | —— | ——— | ——— | —— | ——— |
| 1895 | ——— | —— | ——— | ——— | —— | ——— | ——— | —— | ——— |
| 1896 | Jan. 1 | 33° | 8,268 | Jan. 25 | 33° | 5,928 | ——— | —— | ——— |
| 1897 | ——— | —— | ——— | ——— | —— | ——— | ——— | —— | ——— |
| 1898 | ——— | —— | ——— | ——— | —— | ——— | Mar. 22 | 51° | 1,720 |

| Year | Date | Temp. | No. | Date | Temp. | No. | Date | Temp. | No. |
|---|---|---|---|---|---|---|---|---|---|
| 1894 | ——— | —— | ——— | ——— | —— | ——— | ——— | —— | ——— |
| 1895 | Apr. 29 | 64° | 67,338 | ——— | —— | ——— | ——— | —— | ——— |
| 1896 | Apr. 24 | 72° | 1,012,350 | May 25 | 75° | 4,400 | ——— | —— | ——— |
| 1897 | ——— | —— | ——— | May 25 | 66° | 16,000 | ——— | —— | ——— |
| 1898 | ——— | —— | ——— | May 3 | 60° | 451,200 | June 14 | 83° | 1,000 |

| Year | Date | Temp. | No. | Date | Temp. | No. | Date | Temp. | No. |
|---|---|---|---|---|---|---|---|---|---|
| 1894 | July 30 | 82° | 1,908 | ——— | —— | ——— | Sept. 4 | 78° | 13,650 |
| 1895 | July 6 | 81° | 3,710 | Aug. 21 | 81° | 47,480 | Sept. 20 | 79° | 2,223 |
| 1896 | July 23 | 78° | 12,600 | Aug. 3<br>" 15 | 80°<br>81° | 39,200<br>12,800 | Sept. 30 | 58° | 14,000 |
| 1897 | July 30 | 84° | 11,200 | Aug. 31 | 80° | 1,398,000 | ——— | —— | ——— |
| 1898 | July 19 | 84° | 6,400 | Aug. 16 | 77° | 38,400 | Sept. 27 | 73° | 83,200 |

| Year | Date | Temp. | No. | Date | Temp. | No. | Date | Temp. | No. |
|---|---|---|---|---|---|---|---|---|---|
| 1894 | ——— | —— | ——— | ——— | —— | ——— | ——— | —— | ——— |
| 1895 | ——— | —— | ——— | Nov. 27 | 33° | 320,915 | ——— | —— | ——— |
| 1896 | ——— | —— | ——— | ——— | —— | ——— | Dec. 29 | 35° | 14,120 |
| 1897 | Oct. 12 | 65° | 1,605,600 | Nov. 23 | 43° | 1,160 | ——— | —— | ——— |
| 1898 | Oct. 25 | 49° | 8,500 | Nov. 15 | 41° | 1,100 | Dec. 15 | 32° | 3,100 |

The pulses recorded in the table will be found to coincide (Table I.) with those of other species of the genus, and in the main with those of the total *Ploima*, thus indicating that this species responds, along with other rotifers, to some common factor of their environment. The relation of these pulses to those of the chlorophyll-bearing organisms (Pl. I. and II.) is also striking. Of the 30 pulses recorded in the table, 6 fall outside of the period included in Plates I. and II. Of the remaining 24 there are 17 whose culminations in the main coincide with those of the organisms upon which they feed, and 5 of the 6 remaining follow shortly thereafter, usually at the next collection, at an interval of a week or thereabouts. In one case only is there a delay of a fortnight after all of the plant pulses. The large pulses of August–October, 1897, were judged by the *Chlorophyceæ* only, as these overtop the other plants so greatly. The pulse of August 31 occurs a week before the culmination of the *Chlorophyceæ* is reached, but in the presence of abundant food. The dependence of these pulses of *Brachionus pala* upon the food supply is plainly suggested by their time relations with the pulses in the plant life of the plankton.

Further reason for concluding that the species is polycyclic is found in the evidences of sexual reproduction, which will be noted in connection with the discussion of the varieties. In this connection it will suffice to say that there is some evidence that the pulses are preceded by rapid parthenogenetic reproduction, and accompanied or followed by the appearance of male eggs, males, and winter eggs.

The eggs of *Brachionus pala* are detached from the parent in such a large proportion of the cases in preserved material that the tracing of the reproductive cycle by means of *attached* eggs is rendered difficult if not impossible. Furthermore, eggs resembling the winter eggs of this species, and provisionally referred to it in our records, are to be found in the plankton at nearly all seasons of the year, and it is obviously impossible to determine the time at which they were produced. It seems probable that all of the varieties pass through recurrent cycles, and that none of them is a temporary phase of the cycle.

Outbreaks of parasitic diseases in this species are very common. They almost always attend the larger pulses, but isolated individuals infested by some of these pests are not infrequent, especially during the summer months. Thus in the vernal pulse of *pala* (type only) reaching 716,982 on April 24, 1896, 19,056 individuals were parasitized by *Bimœrium hyalinum* Przesm., or by something very similar to it, and 30,966 were infested by a fungus-like growth. This is about 7 per cent. of the total individuals. Similar though less pronounced outbreaks have attended other vernal and autumnal pulses. Species of *Colacium* are sometimes found attached to the loricæ of this species.

*Brachionus pala* is exceedingly variable, especially in the matter of the development of the posterior spines. Forms without the spines (*pala* type) intergrade, by only slight gradations, into those with fully developed spines (var. *amphiceros*). The angle which these spines make with the lorica is also a matter of great variation, in preserved material at least. Individuals with the spines at right angles to the antero-posterior axis are occasionally seen. The species also varies in the matter of the dorsal-ventral curvature of the antero-median spines (var. *dorcas*). Individuals with such curved antlers are sometimes provided with posterior spines (var. *dorcas* form *spinosus*). I have followed Weber ('98) in placing *B. amphiceros* Ehrbg., *B. dorcas* Gosse, and its form *spinosus* Wierz. as varieties of *B. pala*. They do not, however, all stand upon an equal footing. *B. amphiceros* grades imperceptibly into *B. pala*, and has the same seasonal distribution. *B. dorcas* and its form *spinosus* intergrade with each other as do *pala* and *amphiceros*, and they also exhibit some intergradations with *B. pala*; but they are winter varieties, or at least belong to the colder season, as will appear later. Their differentiation in this respect is thus more striking than that of *B. amphiceros*, and makes it probable that we have in *dorcas* a seasonal variety of *B. pala*. Zacharias ('98) has reduced *B. pala* to a variety of *B. amphiceros* because in his opinion the latter is the more widely distributed form in certain pond waters which he examined. This is a criterion which presupposes a wide knowledge of distribution and numbers, and, furthermore, a basis which can not fail to add to the confusion already existing in this genus, since it is hardly to be hoped that it will lead to the same conclusion in the hands of different investigators in different regions, or even in different seasons and years in the same region. As an illustration of the difficulties which might arise I may cite the yearly averages of *amphiceros* and *pala* in the table on page 182. In three years the latter is more abundant, and in two, the former. The relative abundance of these forms in the river at a given point of collection is an epitome of their distribution in a wide area of channel and backwaters. An application of the principle advanced by Zacharias would in this instance lead to constant change. The retention of *pala* (Ehrbg., 1830) as the type and *amphiceros* (Ehrbg., 1838) as the variety is in keeping with priority in nomenclature and with the principle of regarding the more highly differentiated or divergent form as the variety. Variety *amphiceros* occupies thus the same relation to the type that *bidens* does to its type *angularis*. Both are illustrations of the tendency common to all species of *Brachionus* to develop posteriorly directed spines.

I shall proceed to discuss the salient points in the seasonal distribution and statistics of the several varieties:—

*Brachionus pala* Ehrbg., type.—Average number of individuals, 2,693; of eggs, 20,809, including all free eggs referable to the species in the broader sense. In the present connection I shall call attention only to the fact that the type form, without the posterior spines, is less abundant during the midsummer interval than the spinous variety *amphiceros*. This appears in Table I., and is to be found in the records of years prior to 1898. A fuller comparison of the records of the two forms will be made in the discussion of *amphiceros*. I shall not discuss the recurrent pulses of this form or of *amphiceros*, since as they dominate those of the species as a whole it would lead to considerable repetition. The pulses of *pala* in the main (Table I.) coincide in location with those of the species as a whole, and the direction of movement of the seasonal curve of distribution is quite similar, save in the fact that the amplitude of the pulses is less, and that the differences in seasonal distribution between *pala* and *amphiceros* modify the curve of each.

The decisive evidence of sexual reproduction in the species in the form of *attached* male and winter eggs is found repeatedly at times of the major pulses. In some instances they appear during the rise of the pulse. The autumnal pulse of 1895 will serve as an illustration of the character of these statistical data. (See following page.)

This pulse is sustained much longer than usual, but it serves to show the prevalence of parthenogenetic eggs during the rise of the pulse, and the evidence of sexual reproduction during its progress. In some other instances the number of free winter eggs *after* the

Brachionus pala, Type Form. Sexual Cycle.

| 1895 | Males | Male eggs carried | Winter eggs | | Summer eggs | | Total eggs* | Total individuals |
|---|---|---|---|---|---|---|---|---|
| | | | Free* | Carried | Free* | Carried | | |
| Oct. 30..... | — | — | — | — | 96 | — | 96 | 48 |
| Nov. 5..... | — | 765 | 765 | 85 | 1,700 | 3,060 | 6,375 | 6,885 |
| Nov. 14..... | 4,140 | 8,280 | 7,245 | — | 63,135 | 71,415 | 150,075 | 134,550 |
| Nov. 20..... | — | 1,680 | — | — | 43,680 | 68,880 | 114,240 | 189,280 |
| Nov. 27..... | — | 742 | 2,226 | — | 46,746 | 89,040 | 138,754 | 217,777 |
| Dec. 4..... | — | 1,380 | — | — | 68,310 | 66,240 | 135,930 | 211,830 |
| Dec. 11..... | — | 424 | — | — | 16,112 | 17,384 | 22,472 | 36,464 |
| Dec. 18..... | — | — | — | — | 17,808 | 1,113 | 18,921 | 14,469 |
| Dec. 25..... | — | — | — | — | — | 371 | 742 | 371 |

* Includes free eggs of other varieties also.

culmination of a pulse is very large. For example, the sudden vernal pulse of 716,982 on April 24 is accompanied by 28,584 free winter eggs. The pulse declines to 22,224 on April 29, and the free winter eggs rise to 95,841, and the empty loricæ to 26,114.

Females carry 1–5 summer eggs, and 1–8, or even more, male eggs. There is great variation in the size of the summer eggs, these and the male eggs appearing almost to intergrade.

*Brachionus pala*, including *B. amphiceros*, is a common constituent of the plankton of shallow warm waters. It has not been reported from the larger and cooler lake waters by Apstein ('96), Burckhardt ('00 and '00a), or Jennings ('94, '96, and '00). Zacharias ('98) and Marsson ('00) find it in the summer plankton of smaller lakes and ponds in Germany. Seligo ('00) records it from April to October, with a maximum in August, in Prussian lakes; and Lauterborn ('98a) finds it to be perennial and polycyclic in the Rhine. Schorler ('00) reports both *pala* and *amphiceros* from the Elbe, the former being abundant in May and sporadic during the summer, while the latter was abundant in April, June, and September, and rare at other times during the warmer months. Zimmer

('99) finds *amphiceros* in the Oder, where it appears in April and increases until the end of August or the first of September, when it is the most abundant animal in the plankton. In no one of these instances was the examination so long continued or made at such short intervals as in the case of the exploration of the Illinois. The diversity exhibited in these different waters may be paralleled by the fluctuations from year to year in the Illinois, and from all the data it may be inferred that the organism is probably perennial and polycyclic, the number of pulses depending upon local conditions, primarily of the food supply.

*Brachionus pala* var. *amphiceros* Ehrbg.—Average number of females, 17,071; of eggs, 5,103. The numbers were much larger (158,299 and 35,392) in the stable conditions of 1897, and still smaller (5,430 and 715) in the disturbed conditions of 1896.

The seasonal distribution of this variety with respect to that of the type constitutes the chief point of interest in the records. It is present throughout the whole range of temperatures, shares in the vernal and autumnal pulses noted for the species as a whole, but constitutes a much greater proportion of the *amphiceros-pala* group during the warmer months than it does in the colder ones. Thus, as shown in the accompanying table, the proportion which *amphi-*

SEASONAL DISTRIBUTION OF BRACHIONUS PALA AND B. PALA VAR. AMPHICEROS.

| Year | June 1 to Oct. 1 | | | | Oct. 1 to June 1 | | | |
|---|---|---|---|---|---|---|---|---|
| | *pala* | | *amphiceros* | | *pala* | | *amphiceros* | |
| | No. | Per cent. | No. | Per cent. | No. | Per cent. | No. | Per cent. |
| 1895........ | 7,042 | 4 | 155,324 | 96 | 863,247 | 71 | 336,618 | 29 |
| 1896........ | 14,637 | 14 | 89,400 | 86 | 958,265 | 87 | 144,087 | 13 |
| 1897........ | 14,600 | 4 | 3,776,400 | 96 | 719,650 | 44 | 912,580 | 66 |
| 1898........ | 10,440 | 4 | 229,720 | 96 | 129,623 | 17 | 657,960 | 83 |
| Average..... | 11,679 | 6.5 | 1,062,711 | 93.5 | 667,696 | 55 | 512,811 | 45 |

*ceros* forms of this group in the period from June 1 to October 1 is from 86 to 96 per cent., averaging 93.5 per cent. in the several years. On the other hand, in the colder months—Jan. 1 to June 1 and Oct. 1 to June 1—the per cent. is only from 13 to 83, averaging 45. The temperatures on June 1 (Pt. I., Pl. IX.–XII.) average about 75°, and on Oct. 1 about 67°. The spinous form (*amphiceros*) thus includes about 45 per cent. of the individuals at low temperatures, and 93.5 per cent. at high temperatures; and the smoother form (*pala* type), 55 per cent. and 6.5 per cent., respectively.

This predominance of the spinous variety at high temperatures is apparently a striking illustration from statistical evidence of the hypothesis of Wesenberg-Lund ('00) that such elongations of the body of planktonts are adaptations to the lessened buoyancy of the warmer water. This relation of the spinous form to higher temperatures is evident in every year, 1895–1898, and the proportion of spinous forms, 86–96 per cent., exhibits all the constancy that might at the best be expected in plankton data. The relation is generally apparent (Table I.) in the individual entries as well as in the sums total, and, considering the numbers concerned and the long period of observation, should have more weight than some of the exceptions to the hypothesis, which have been or will be noted, in which the data are less extensive. For example, *Brachionus pala* var. *dorcas* does not in its seasonal distribution support the hypothesis, but owing to its small numbers—especially of the form *spinosus*—less weight should attach to its evidence.

In 1897 the first autumnal pulse of the *pala* group consisted almost entirely of var. *amphiceros*. This pulse started August 10 at 3,600, culminated August 31 at 1,398,000, and declined to 800 September 29. Of the 3,500,200 individuals included in this pulse, all but 11,400 belonged to *amphiceros*. The temperatures recorded during this period ranged from 83° to 71°. A second pulse started October 5 at 1,600, culminated October 12 at 1,605,600, and declined to 0 on October 26. Of the total individuals (1,609,000) included in this pulse, 894,800 belonged to *amphiceros* and 714,200 to *pala*. The range in recorded temperatures in this period was from 71° to 59.5°. This may serve as an additional illustration of the relation of temperature to the spinous variety of *Brachionus pala*.

This variety is itself polycyclic, as is evidenced by the recurrence of male and winter eggs carried by the female at times of the pulses.

Owing to the ease with which such eggs are detached, the records are quite imperfect indices of the actual numbers. In 1898 male eggs (carried) to the number of 70,400 per m.[3] attended the culmination of the vernal pulse (419,200) on May 3. Winter eggs (carried) were recorded twice on the decline of the pulse of August 16; once on the decline of that of October 25; and once on that of December 15.

*Brachionus pala* var. *dorcas* Gosse.—The seasonal distribution of this variety is so sharply defined that it merits especial attention. The following table gives the dates and temperatures of last and first records in each year.

SEASONAL LIMITS OF BRACHIONUS PALA VAR. DORCAS.

| Year | Last records | | First records | | Largest pulses | | |
|---|---|---|---|---|---|---|---|
| | Date | Temp. | Date | Temp. | Date | Temp. | No. |
| 1895 | Apr. 29 | 64° | Oct. 15<br>Nov. 14 | 57°<br>46° | Apr. 29 | 64° | 9,000 |
| 1896 | May 1 | 70° | Nov. 17 | 44° | Apr. 24 | 72° | 183,000 |
| 1897 | Apr. 27 | 60° | Oct. 12<br>Jan. 11, '98 | 65°<br>32° | Apr. 27 | 60° | 2,400 |
| 1898 | Apr. 26<br>May 17 | 57°<br>64° | Dec. 6 | 34° | Apr. 26 | 57° | 4,000 |

The species practically disappears at the end of April, when temperatures rise above 70°, and it does not return to the plankton until they fall, in October and November. Its period of continuous occurrence does not begin in years of greatest numbers until temperatures reach 45°, and it remains throughout the period of minimum temperatures. As the collection-averages indicate, this species is relatively rare, and its numbers, even in its largest pulses, are usually smaller than those of the other varieties which it accompanies. Although this species is a winter planktont it reaches its greatest development during the spring pulse, indicating an optimum near 65°, though it does not recur in numbers when this temperature returns in autumn. There is a single autumnal pulse in 1895 of 8,625, on November 14, at 44°, accompanying pulses in the other varieties. There was also one midsummer record.

The curvature of the median anterior horns which defines this variety results in a considerable elongation of these processes. With regard to the idea of Wesenberg-Lund ('00) that this tendency on the part of plankton organisms to elongate in "Balanceapparat" is an adaptation to the lessened buoyancy of the warmer water of summer, it must be said that it seems difficult to apply this hypothesis in the case of *B. pala* var. *dorcas*, which is probably a seasonal variety confined to *winter* months. I have no data, however, on the relative development of these processes in *B. pala* at different temperatures, beyond the seasonal limitation of this variety to lower temperatures when it should be least expected according to the hypothesis.

*Brachionus pala* var. *dorcas* has not been found widely distributed in the fresh-water plankton, or at least not reported separately from *B. pala*, which is widely distributed. Skorikow ('96) reports it from Charków, Russia; and Kertész ('94), in January from Budapest.

*Brachionus pala* var. *dorcas* forma *spinosus* Wierz.—Average number of females, 33; of eggs, 2. This form was always sporadic in its appearance in our plankton. Of 12 occurrences, 3 were in April, 2 each in November, December, and July, and one each in January, May, and August. The whole seasonal range of temperatures is thus included. It may be of significance for Wesenberg-Lund's hypothesis that the spinous form of *dorcas* makes over 50 per cent. of its appearances between April 1 and September 30, whereas *dorcas* itself is much less abundant relatively within these limits. The largest occurrence of *spinosus*—100,044 on April 24, 1896—was marked by the fact that 97.5 per cent. of the individuals were infested with fungi. The nearest approaches to pulses in this form are the November–December appearances in 1895 and 1896. Females with winter eggs were recorded December 29 in the latter year.

*Brachionus quadratus* Rousselet.—Individuals corresponding to Rousselet's description have been found occasionally in the plankton from the last of May till the middle of August at temperatures of 70° and above. The species is somewhat closely related to the *bakeri* series, and may ultimately prove to belong to it. Rousselet ('97) is of the opinion that it is distinct by reason of the truncate posterior end, the absence of foot sheath, the reticulations of the shell, and the semi-jointed foot. It occurred only in small numbers, and forms intermediate between it and *bakeri* were not recorded. This is, I believe, the first record of its occurrence in American waters.

*Brachionus urceolaris* Ehrbg.—Average number of individuals including all varieties, 468; of eggs, 56. The species was relatively quite abundant in 1897 (5,290 and 1,976) in the stable conditions then prevailing, but less so in the recurrent floods of 1896 (1,020 and 494). It is not a common species, being outranked by *B. angularis*, *bakeri*, *budapestinensis*, and *pala*. The species as a whole is found throughout the entire year, though never in large numbers since 1895. The following table, which gives the principal pulses in the several years, shows the wide range of the species and its varieties in seasonal distribution.

PULSES OF BRACHIONUS URCEOLARIS.

| Year | Date | Temp. | No. | Date | Temp. | No. |
|---|---|---|---|---|---|---|
| 1894 | ——— | ——— | ——— | ——— | ——— | ——— |
| 1895 | ——— | ——— | ——— | ——— | ——— | ——— |
| 1896 | Mar. 24 | 41° | 2,727 | Apr. 17 | 66° | 8,398 |
| 1897 | ——— | ——— | ——— | Apr. 27 | 60° | 6,400 |
| 1898 | Mar. 22 | 51° | 2,000 | Apr. 26 | 57° | 6,400 |

| Year | Date | Temp. | No. | Date | Temp. | No. | Date | Temp. | No. |
|---|---|---|---|---|---|---|---|---|---|
| 1894 | ——— | ——— | ——— | ——— | ——— | ——— | Aug. 15 | 84° | 181,764 |
| 1895 | June 19 | 80° | 324,254 | ——— | ——— | ——— | ——— | ——— | ——— |
| 1896 | ——— | ——— | ——— | July 23 | 80° | 10,000 | ——— | ——— | ——— |
| 1897 | ——— | ——— | ——— | ——— | ——— | ——— | ——— | ——— | ——— |
| 1898 | ——— | ——— | ——— | ——— | ——— | ——— | ——— | ——— | ——— |

| Year | Date | Temp. | No. | Date | Temp. | No. | Date | Temp. | No. |
|---|---|---|---|---|---|---|---|---|---|
| 1894 | ——— | ——— | ——— | ——— | ——— | ——— | ——— | ——— | ——— |
| 1895 | Sept. 5 | 74° | 4,293 | ——— | ——— | ——— | Dec. 4 | 32° | 345 |
| 1896 | ——— | ——— | ——— | ——— | ——— | ——— | Dec. 3 | 32° | 794 |
| 1897 | Sept. 21 | 71° | 121,200 | Oct. 5 | 71° | 800 | ——— | ——— | ——— |
| 1898 | Sept. 6 | 79° | 5,600 | ——— | ——— | ——— | Dec. 13 | 33° | 500 |

There is some tendency, especially in later years, toward the colder months. Eight of the fifteen pulses occur below 70°, and twelve between September 1 and May 1.

On account of the small numbers the pulses are poorly defined in our records (Table I.), but there are indications that they coincide in location, in a general way, with those of other *Brachionidæ* and the *Ploima* as a whole. They also in many instances coincide with or follow shortly after the pulses of chlorophyll-bearing organisms, as has been noted in other *Brachionidæ*.

This species, *B. urceolaris*, is a cosmopolite, and of general occurrence in the fresh-water plankton of smaller and warmer bodies of water. It is reported by Weber ('98) from Swiss marshes, by Zacharias ('98) and Marsson ('00) from many smaller German waters, and by Seligo ('00), throughout the year, from lakes near Danzig, where it attains maxima in April, July, and September. Since this author includes *B. angularis* (*B. urceolaris* forma *angulatus* Seligo) with his records of *urceolaris*, it is probable that the species in the usual sense may have much more restricted numbers and range in his region. Kertész ('94) finds it about Budapest. It is reported as sporadic in the vernal plankton of the Elbe by Schorler ('00), and is listed from the Oder by Zimmer ('99). Skorikow ('97) reports it once in summer plankton of the Udy near Charkow.

The species is exceedingly variable in the development of the anterior spines, and in the proportions of the body. It varies toward the *bakeri* group, and individuals are sometimes found which seem to connect the two groups. I follow Skorikow ('96) in placing *B. rubens* as a variety of *B. urceolaris*, including in it those forms whose anterior spines are least developed. The more slender summer forms I have listed as var. *bursarius* Barrois and v. Daday. From my observations on *B. variabilis* Hempel, I am inclined to regard it as a possible variety in the *urceolaris* group. In form, texture, proportions, and anterior spines it is certainly similar to this group. The presence of the posterior spines would not suffice to separate it, since these may or may not be present, and the existence of a variety of *urceolaris* with such spines would only present a phenomenon parallel to that observed in *pala*, *angularis*, and *bakeri*. The quadrate foot-plate present in *variabilis*, which, according to Hempel ('96), is not found in other species of the genus, serves to distinguish this form, and in the absence of proof of its occurrence in forms of *urceolaris* as here defined I prefer to leave *variabilis* as a separate species. In any event it is closely related to the *urceolaris* group, and may ultimately be found to belong within its seasonal range of variation. Seligo ('00) has suggested that *B. angularis* is also a variety of *urceolaris*, but I do not so regard it. The averages of the different forms in the several years are given in the table on the next page, which also includes *B. variabilis*. The discussion of the different varieties follows:—

*Brachionus urceolaris* Ehrbg., type.—Average number of individuals, 18. The type form was not abundant in any year, and its appearances were sporadic. It was recorded in February, June, and July. It includes less than one per cent. of the individuals referred to this species.

*Brachionus urceolaris* var. *rubens* Ehrbg.—Average number of individuals, 244; of eggs, 41. This variety was more abundant during the stable conditions of 1897 (5,290 and 1,976) and the low-water years of 1894 and 1895. It includes over 99 per cent. of all the individuals referred to this species.

It is apparently the winter form of the species. This appears clearly in its seasonal distribution in the later years, but in 1894 and 1895 it was found in summer months and in large numbers. It is thus capable of development in the whole range of temperatures.

The pulses recorded in the table on page 193 are in the main composed of this variety. It is quite abundant during the summer of 1894, attaining a pulse of 181,764 on August 15 at 84°, disappearing in September, and not reappearing until the April collection. It attains a pulse of 324,254 on June 19 at 80°, declines in July, then occurs sporadically until the following February. It then continues till June 6, with a pulse of 8,398 on April 17 at 66°. An isolated occurrence of 10,000 in July is the only record in the summer of 1896. It is in the November–December plankton of 1896 and the March–May plankton of 1897, and attains a pulse of only 6,400 on April 27, at 60°. It does not reappear until the 14th of the following September, in whose stable conditions a pulse of 121,200 on the 21st, at 71°, is found. It disappears October 5, and is irregularly present from January to April, with larger numbers in the latter part of the period. It is not found in 1898 (Table I.) from May 1 to Decem-

Brachionus urceolaris and Varieties, and B. variabilis. Average Number per Collection.

| Year | No. of collections | *urceolaris* | | var. *rubens* | | var. *bursarius* | | Total *urceolaris* | | *Brachionus variabilis* | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ♀ | Eggs | ♀ | Eggs | ♀ | Eggs | ♀ | Eggs | ♀ | Eggs |
| 1894 | 10 | 5 | 0 | 32,721 | 16,305 | 0 | 0 | 32,726 | 16,305 | 17,156 | 5,395 |
| 1895 | 31 | 34 | 120 | 11,123 | 265 | 0 | 0 | 11,157 | 385 | 48 | 7 |
| 1896 | 43 | 7 | 7 | 986 | 487 | 27 | 0 | 1,020 | 494 | 170 | 14 |
| 1897 | 30 | 0 | 0 | 5,290 | 1,976 | 0 | 0 | 5,290 | 1,976 | 146 | 66 |
| 1898 | 52 | 18 | 0 | 244 | 41 | 206 | 15 | 468 | 56 | 4 | 0 |
| Total | —— | 64 | 120 | 50,364 | 19,074 | 233 | 15 | 50,661 | 19,206 | 17,524 | 5,482 |

ber 1, but is continuously present in the winter of 1898–99 from December 6 till March 28, when collections ceased.

Male eggs were recorded but once—April, 29, 1895—and there is no other evidence of the cycles of reproduction beyond the pulses in numbers. They suggest a polycyclic habit with major pulses in spring and fall. It is apparent that conditions affect these cycles greatly, as is seen, for example, in the contrast between the earlier years, with low water in the spring, and the later ones, when high water was longer continued.

This variety, *rubens*, has not been widely reported in the plankton. Skorikow ('96) finds it in June in the River Udy, and Kertész ('94) reports it from Budapest, while Stenroos ('98) finds it in the littoral fauna of Lake Nurmijärvi in Finland, and also in the plankton in July and August.

*Brachionus urceolaris* var. *bursarius* Barrois and v. Daday.—Average number of individuals, 206; of eggs, 33. This is a summer variety, and forms but a small part—less than one per cent.—of the total number of individuals referred to the species.

*Brachionus variabilis* Hempel.—This species was found but once in 1898, but was more abundant in former years (see table on opposite page). The largest development which it attained in the Illinois was a pulse of 168,222 on August 15, 1894, at 84°. The largest number in subsequent years was 5,200 per m.$^3$ on August 8, 1896. It may be significant of the connection of this form with the *urceolaris-rubens* group that the great pulse of 1894 was coincident with an unusual development of *rubens* on that date.

This species is a summer form, the earliest record being May 24, 1898, at 74°, and the latest September 25, 1895, at 73°. Its optimum temperatures lie near the summer maximum. If this form should prove to be merely a spinous variety of *B. urceolaris* it will afford another illustration of spinous varieties of *Brachionus* appearing at high temperatures, in accordance with the hypothesis of Wesenberg-Lund ('00).

In Table I. there is given for 1898 the seasonal distribution of the free winter eggs of *Brachionus*. It will be seen that they occur throughout practically the whole year, with some increase after the times of the April–May and September pulses.

*Cathypna leontina* Turner.—Average number, 47, in 1896, a year of disturbed hydrograph; less abundant in previous years, and not recorded in subsequent ones. Earliest record, June 17, at 76°; and latest, October 2, at 63°. Always present in small numbers and evidently adventitious.

*Cathypna luna* (Ehrbg.) Gosse.—Average number, 47. Found in every month but November, though always in small numbers and irregularly. All but six of the thirty-three records fall between April 1 and October 3 and above 50°. Over half of all the individuals were found in 1896. This fact, together with the nature of the seasonal distribution, indicates plainly its adventitious character.

*Cathypna rusticula* Gosse.—Found once, March 22, 1897, at 44°. Not previously reported from American waters.

*Cœlopus porcellus* Gosse.—Average number, 106. From March to September, at 37° to 80°, and apparently adventitious.

*Colurus bicuspidatus* Ehrbg.—Average number, 274. This species is apparently a winter planktont. In 1897 it appeared first November 9, at 50°, and was found somewhat irregularly through the winter until May 17, at 64°. There is a pulse March 15, at 46°, of 6,400. Ovigerous females were found during the rise of the pulse, and males on April 12, on its decline. A few scattered records were made in the following winter, beginning November 8, at 46°. It occurs in the plankton during flood season and may be adventitious.

*Colurus obtusus* Gosse.—Average number, 38. In small numbers and irregularly in March and April at temperatures below 50°, and in September at 73°. Hempel ('99) lists also *C. deflexus* Ehrbg.

*Diglena circinator* Gosse.—Average number, 121, in 1896; a year when many adventitious rotifers were brought into the plankton by disturbed hydrographic conditions. All the records lie between April 29, at 70°, and July 28, at 81°. An ovigerous female was found in July. The species is adventitious in the plankton.

*Diglena forcipata* Ehrbg. was recorded once—October 12, 1897, at 65°.

*Diglena giraffa* Gosse was observed but once in the river plankton. Not before recorded from American waters.

*Diglena grandis* Ehrbg. was recorded in July and September at 76° and 79°.

*Diglena uncinata* Milne was found August 12, 1898, at 82°.

Hempel ('99) reports *D. biraphis* Gosse and *D. catellina* Ehrbg. in waters immediately tributary to the river. All members of the genus belong to the littoral fauna among vegetation, and are adventitious in the plankton of open water.

*Euchlanis pyriformis* Gosse.—Recorded April 12, 1898, at 52°. Hempel ('99) reports it from June to October in collections in the river in 1894 and 1895.

*Euchlanis triquetra* Ehrbg.—Average number, 19. Found irregularly from July to November at 84° to 41°. Hempel ('99) reports it also in June. It is probably adventitious.

Hempel ('99) also reports *E. dilatata* Ehrbg. in the river from July to September, and *E. deflexa* Gosse in tributary waters.

*Gastropus stylifer* Imhof.—A rotifer doubtfully referred to this species was found sporadically in the plankton of the river. It was recorded in June, 1894, and July, 1896, at temperatures above 75°. It was almost continuously present in 1896 from February 20 to April 10, and again on November 17 and December 3. It did not reappear until January 31, 1899, from which time it continued present until the close of operations in March. Most of these occurrences are at minimum temperatures and all of them below 45°. I have followed Weber ('98) and Jennings ('00) in using Imhof's name *Gastropus stylifer* instead of *Hudsonella picta* Zach. or *Notops pygmæus* Calman, by which names the species has been frequently designated. The evidence from our records indicates that it is a somewhat sporadic winter planktont in our waters. Lauterborn ('93) finds it to be a perennial planktont in the Rhine, with its largest numbers in summer.

*Hydatina senta* Ehrbg. was found September 20 at 73°. Hempel ('99) also reports it in towings from the river in March and July, 1895. This species is very common in European waters, but has as yet been found in America only in the Illinois River and, by Kellicott ('88), at Corunna, Mich.

*Mastigocerca bicornis* Ehrbg.—Average number, 42. Found irregularly and in small numbers from June 28 to September 13 above 63°. Hempel ('99) reports it from Quiver Lake among vegetation, and it is evidently adventitious in the river plankton.

*Mastigocerca bicristata* Gosse was found but once, late in September, 1895, at 73°, but it is more abundant in the backwaters.

*Mastigocerca carinata* Ehrbg.—Average number, 1,674. This species was present in the plankton from the middle of June till the first of October, and at irregular intervals and in small numbers in fall and winter months. The distribution in years prior to 1898 falls within the limits shown in Table I. In this year the bulk of the occurrences lie between June 21 and August 4, and above 77° and 72°. The optimum lies near the summer maximum, though occurrences at minimum temperatures in March and December reveal acclimatization to a wide range of temperatures. In this year there are several somewhat irregular pulses, the best-defined of which follow the pulses of chlorophyll-bearing organisms (cf. Table I. and Pl. II.) at an interval of one or two weeks. The species was not recorded so frequently in previous years, in some of which also pulses are indicated. These pulses are not consequent upon floods, and the species is apparently not adventitious in the plankton but a normal constituent. Apstein ('96) reports *M. capucina* as abundant in Dobersdorfer Lake from June to October—a seasonal distribution similar to that found in the Illinois River for *M. carinata*.

*Mastigocerca elongata* Gosse was found once—March 28, 1899, at 38°. Hempel ('99) reports it in June in Quiver Lake.

*Mastigocerca mucosa* Stokes was taken in August to October, 1898, at 82°–62°, in small numbers. It is reported by Jennings ('00) as "one of the most abundant of the *Rotifera* among the vegetation of the shallow parts of Lake Erie," but it was not reported by Hempel ('99) in similar environment about Havana.

*Mastigocerca stylata* Gosse was found in the plankton in small numbers in June and July at temperatures approaching 80°. Hempel ('99) reports it also in August.

In addition to the species of this genus above listed, Hempel ('99) records *M. lata* Jennings. There are also in our records a considerable number of individuals referred to this genus but not specifically identified. Many of these belong to one, or possibly several, very small species. They are most abundant during the summer months, reaching a pulse of 16,800 on June 28. They occur in large numbers in the filter collections (average for 1898, 798; filter-paper, 145,384), and, it seems, must escape with ease through the silk net on account of their small size and their active movements.

A number of species in this genus have been described of late from the fresh-water plankton, but in the present state of the literature of the subject I am not certain to what species these forms should be referred. The genus is sadly in need of critical revision. It includes a number of semi-limnetic species, whose importance in the plankton will probably be revealed by more perfect methods of collection.

*Metopidia lepadella* Ehrbg. was found only in March and June at temperatures above 46°. It is apparently adventitious.

*Metopidia oblonga* Ehrbg. was found once—July 29, 1895, at 75°.

*Metopidia salpina* Ehrbg. was recorded June 28, 1898, at 78°.

*Metopidia solidus* Gosse.—Average number, 67. This is the most abundant representative of the genus in our plankton. It was recorded from March 15 to November 14, at temperatures above 45°. Most of the occurrences are in the summer months (Table I.), at maximum temperatures. The numbers are small, the occurrences irregular, and the species evidently adventitious.

*M. rhomboides* Gosse is recorded by Hempel ('99) from the river plankton, as also *M. acuminata* Ehrbg., *triptera* Ehrbg., and *bractea* Ehrbg. from the backwaters.

*Monostyla bulla* Gosse.—Average number, 50. Present in small numbers and irregularly from April till the middle of October at temperatures above 50°. It is evidently adventitious. Jennings ('00) finds this one of the most abundant rotifers among the aquatic vegetation in Lake Erie. It is in our waters the most abundant of the genus in the plankton, especially in the vegetation-rich backwaters.

*Monostyla lunaris* Ehrbg.—Average number, 37. Found in the extremes of the temperature range, but over 50 per cent. of the occurrences are in August–October. Its numbers are always small and its occurrences irregular. It is plainly adventitious.

*Monostyla quadridentata* Ehrbg.—Average number, 10. This species was found in the plankton irregularly in July–September, at maximum temperatures. It is abundant (Hempel, '99) in the backwaters, where vegetation is abundant, and is apparently adventitious in the plankton. In addition to the species here recorded Hempel ('99) lists *M. cornuta* Ehrbg. and *M. mollis* Ehrbg. from collections in the river, and *M. closterocerca* Schmarda from the backwaters. This is an exceedingly variable group, and will repay a thorough revision in the light of a study of the variation of its species. A considerable reduction in the number of these so-called species will doubtless result from such a study.

*Noteus quadricornis* Ehrbg.—Average number, 19. This is a rare species in the plankton, being found in 1895 and 1896 in July at maximum temperatures, and in 1898, on April 12, at 52°, and on November 8, at 46°.

*Notholca longispina* Kell.—This species, which has been found in the summer plankton of many European and American waters, especially our Great Lakes, was noted but once in the Illinois—in January, 1895 (Hempel, '99). It seems to prefer cooler and purer waters.

*Notholca striata* Ehrbg.—Average number, 437, including varieties. This is a winter planktont in our waters, appearing in 1897 on November 30, at 34°, reaching a maximum of 10,840 March 22 (Table I.), at 51°, and disappearing April 19, at 52°. It reappears the following autumn on November 1, at 45°, and attains a maximum of 4,000 March 21, at 37°. In previous years the occurrences all lie within the limits of November 1 and April 24 with the exception of two records in 1895—September 5 and October 15, at 74° and 56°. The spring maximum in 1896 (7,778) was on April 10, at 52°, and in 1897 (4,260) on March 22, at 43°. In each year but a single pulse, that of March–April, is indicated. Minor fluctuations during the winter (Table I.) are in some cases attributable to flood agencies.

The temperature limits of this species are quite definitely established. The species reappears in autumn when 45° is reached, and declines rapidly in the spring after 50° is passed and is but rarely found above 60°. It attains its greatest numbers late in winter or early in spring in the face of flood conditions, though the numbers attained in the channel waters are never very large.

Empty loricæ have been found in the plankton after the decline of the species in April, and females with a single egg were noted in small numbers in 1895 during the rise of the pulse.

I follow the suggestion of Weber ('98) that *N. striata* should include as varieties the following: *N. labis* Gosse, *N. jugosa* Gosse, and *N. acuminata* Gosse. Examination of many individuals in the plankton proves beyond a doubt the great variability of the organism whose seasonal occurrence we have traced. It varies in the length of the posterior spine, in the proportions of the lorica, and in the development of the striæ and the anterior spines. Of a total of 81,227 of *Notholca striata* in this wider sense, 68,887 were referred to var. *acuminata*, 3,852 to var. *jugosa*, 7,029 to *N. striata* in the narrower sense, and 1,469 to other varieties, including var. *labis* and var. *scapha*. The seasonal distribution of *N. striata* (*sensu strictu*) and var. *jugosa* lies within the limits of that of var. *acuminata*, but occurrences are too few to trace their seasonal fluctuations.

This species is reported by Lauterborn ('94) in the winter plankton of the Rhine. He also notes the connecting links between *N. acuminata*, *N. striata*, and *N. labis*, and regards them as belonging to the same "Formenkreis." Apstein ('96) reports *N. acuminata*, *N. labis*, and *N. striata* in lakes of northern Germany and indicates a seasonal distribution which coincides closely with that found for these forms in the waters of the Illinois. He also reports a March–April maximum and only isolated occurrences in midsummer. Forbes ('83) finds the species in the stomachs of young *Coregonus* feeding upon the March plankton of Lake Michigan. Seligo ('00) also finds it in the winter plankton of Prussian waters.

*Notommata cyrtopus* Gosse was found in the plankton in April and September at temperatures above 50°. Hempel ('99) reports *N. aurita* Ehrbg. from the river, and *N. tripus* Ehrbg. and *N. lacinulata* Ehrbg. (=*Diaschiza lacinulata* Ehrbg.) from the backwaters.

*Plœsoma lenticulare* Herrick was found in the plankton of the river from September to December, 1896, throughout the whole range of temperatures from 75° to the winter minimum. Hempel ('99) reports it from May to December, but principally in vegetation

*Polyarthra platyptera* Ehrbg.—Average number of individuals, 86,674; of eggs, 52,560. In 1897, 94,653 and 58,235; in 1896, 29,653 and 11,138; in 1895, 28,947 and 20,074; in 1894, 743 and 217. The effect of the stable conditions of 1897 and of the recurrent floods of 1896 is seen in the larger averages in the former year and in the smaller ones in the latter.

This is one of the most abundant rotifers in our plankton, including, as it does, one seventh of the total *Rotifera*, and exceeding in numbers all other species of the group excepting only *Synchæta stylata*. It is a perennial form, and was recorded in every plankton collection but two, and it may have been present then.

The seasonal distribution of this abundant species is very characteristic of the form which most, though not all, plankton organisms exhibit. Two prominent features are (1) a limitation of large numbers to the warmer months and (2) a rhythmic occurrence of recurrent pulses at approximately monthly intervals. In Plate V. I have plotted the seasonal distribution of this species for the years 1894–99. The plate will serve as one of the best illustrations of the nature of the data contained in my statistical records that could be chosen from them. It illustrates graphically the character of the seasonal distribution of this species and the nature of what I have called recurrent pulses.

In the table which follows, as elsewhere in similar tables, these pulses are listed by the number of individuals attained at their maxima, and are located according to the dates of these maxima.

PULSES OF POLYARTHRA PLATYPTERA.

| Year | Date | Temp. | No. | Date | Temp. | No. | Date | Temp. | No. |
|---|---|---|---|---|---|---|---|---|---|
| 1895 | ——— | —— | ——— | ——— | —— | ——— | ——— | —— | ——— |
| 1896 | Jan. 6<br>" 25 | 32°<br>33° | 5,406<br>2,736 | Feb. 25 | 34° | 7,852 | Mar. 24 | 41° | 57,267 |
| 1897 | ——— | —— | ——— | ——— | —— | ——— | ——— | —— | ——— |
| 1898 | Jan. 25 | 32° | 11,997 | Feb. 22 | 32° | 6,318 | ——— | —— | ——— |
| 1899 | Jan. 17 | 33° | 20,800 | Feb. 14 | 33° | 145,600 | Mar. 7 | 33° | 71,200 |

| Year | Date | Temp. | No. | Date | Temp. | No. | Date | Temp. | No. |
|---|---|---|---|---|---|---|---|---|---|
| 1895 | Apr. 29 | 64° | 86,867 | ——— | —— | ——— | ——— | —— | ——— |
| 1896 | Apr. 24 | 72° | 233,436 | May 8 | 76° | 54,365 | June 1<br>" 11 | 69°<br>73° | 18,000<br>35,200 |
| 1897 | Apr. 27 | 60° | 472,000 | ——— | —— | ——— | ——— | —— | ——— |
| 1898 | Apr. 26 | 57° | 696,000 | May 17 | 64° | 195,200 | June 14 | 82° | 432,800 |

| Year | Date | Temp. | No. | Date | Temp. | No. | Date | Temp. | No. |
|---|---|---|---|---|---|---|---|---|---|
| 1894 | July 30 | 82° | 1,908 | ——— | —— | ——— | ——— | —— | ——— |
| 1895 | July 6 | 81° | 231,504 | Aug. 1<br>" 21 | 79°<br>82° | 6,350<br>117,513 | Sept. 12 | 79° | 19,272 |
| 1896 | July 10<br>" 28 | 80°<br>82° | 90,000<br>71,000 | Aug. 8 | 86° | 39,200 | ——— | —— | ——— |
| 1897 | July 21 | 81° | 172,000 | Aug. 24 | 78° | 230,400 | Sept. 14 | 83° | 50,000 |
| 1898 | ——— | —— | ——— | Aug. 2<br>" 23 | 78°<br>82° | 288,000<br>96,000 | Sept. 27 | 73° | 238,400 |

Pulses of Polyarthra platyptera—*continued.*

| Year | Date | Temp. | No. | Date | Temp. | No. | Date | Temp. | No. |
|---|---|---|---|---|---|---|---|---|---|
| 1894 | Oct. 17 | 58° | 1,140 | ——— | —— | ——— | ——— | —— | ——— |
| 1895 | Oct. 23 | 51° | 408 | Nov. 27 | 33° | 74,942 | Dec. 18 | 39° | 21,147 |
| 1896 | ——— | —— | ——— | ——— | —— | ——— | Dec. 29 | 35° | 37,560 |
| 1897 | Oct. 5 | 71° | 816,000 | Nov. 15 | 47° | 22,400 | Dec. 14 | 40° | 7,300 |
| 1898 | Oct. 11<br>" 25 | 65°<br>49° | 47,500<br>37,500 | Nov. 22 | 40° | 6,000 | Dec. 20 | 33° | 63,400 |

An examination of this table and the graphic presentation (Pl. V.) of the seasonal distribution will show at once the uniformly small numbers attained at low temperatures. Between October 15 and April 15, that is below 60°, no pulse exceeding 100,000 is reached save one of 122,400, February 21, 1899, at 33°. Of all the records in this period only seven exceed 50,000. On the other hand, during the warmer months, above 60°, the pulses have a much greater amplitude. Four of them exceed 400,000, and there are twenty-two records above 100,000. The summer pulses are often separated by minima which approach midwinter levels, but in spite of this the general level of summer occurrences is much higher than that of the colder season. In 1898 the average from April 15 to October 15 was 30,861 per m.$^3$, and for the other months of the year, 15,813, or about half the number in the warmer season. From these facts of distribution it is apparent that though perennial the species finds its optimum conditions at temperatures above 60°. The statement of Hempel ('99) that it thrives best in cold water is not borne out by the statistical examination in any of the years.

The recurrent pulses of this species vary greatly in amplitude. The largest pulse recorded was that of 816,000, October 5, 1897, at 71°. It appeared in a period of prolonged low water and at the close of one of high temperatures continued beyond the usual September limit (Pt. I., Pl. XI.), in a very unusual development of *Carteria* and the smaller algæ of the water-bloom (Pl. II.). Similar autumnal pulses do not appear in other years, the autumnal development as a rule not exceeding to any noticeable degree that of midsummer. There has been in every fully tested spring a large vernal pulse, usually at the time of the spring volumetric maximum, or thereabouts. In 1896 and 1898 it was the largest pulse of the year.

This was not true in other years, but collections in those years were too infrequent to trace the seasonal distribution of the species with accuracy at that season. It is volumetrically of some importance in determining the quantitative fluctuations in the total plankton. Computations based on its average size indicate that approximately 600,000, including eggs, would be required to form 1 cm.[3] of plankton. On this basis, and allowing 10 per cent. for interstices, it constituted at the time of its vernal maximum in 1898 about 10 per cent. of the total volume of the plankton (silk-net catch).

The table on pages 204 and 205 lists 43 pulses, of which 6 lie outside of the period included in Plates I. and II. Of the 38 remaining pulses 16 coincide in location with the whole or a part (in case of divided culminations) of the pulses of the chlorophyll-bearing organisms; 12 follow at the next collection, usually at intervals of one week; and 6, after a fortnight. The remaining 4 do not bear this relation, occurring in autumn or midwinter, when all pulses were feeble and ill-defined. A comparison of Plates I. and II. with V. will show that not all of the chlorophyll-bearing pulses are attended by pulses of *Polyarthra*; nor is there any constant relation, excepting the vernal pulse, between the size of the pulses of the two groups of planktonts in question. Nevertheless, the dependence of the recurrent periods of rapid multiplication of *Polyarthra* upon the rhythmic occurrences of the chlorophyll-bearing organisms upon which they largely depend for their food is strongly suggested by the data here offered. Food relations thus dominate the reproductive cycles.

The pulses of *Polyarthra* form a considerable portion of many of the pulses of the total *Ploima*, and it is but natural that we should find a coincidence in their locations. This may be followed for 1898 in Table I. In a number of instances the culminations of the pulses are not exactly coincident, but separated by the interval between two collections. The association of the two pulses is, however, apparent in every case, and a similar relation may be traced in prior years.

These recurrent pulses afford evidence for the polycyclic habit of this species. Additional proof of this phenomenon is found in the evidences of sexual reproduction—either male or winter eggs attached to the female—which have attended many of the pulses. The eggs of this species, both summer and winter forms, are very readily detached in the manipulation of the plankton, so much so that in 1898 less than 6 per cent. remained attached. More or less uncertainty attends the determination of the parentage of detached winter and male eggs, so that decisive proof of sexual reproduction is best obtained from the attached eggs. In Table I. will be found the records of free and attached male and winter eggs recorded in 1898. Evidence will be found in this of sexual reproduction attending the pulses of March, April, May, September, and December. The presence of winter eggs at intervals throughout the greater part of the year may be due either to their continual production or, as seems more probable, to their continuance in the plankton for some time after their formation. The presence of attached winter eggs, or of larger numbers of free winter eggs, seems to mark the culmination and decline of the pulse. Male eggs, on the other hand, are more generally present during both the rise and decline of the pulses. Somewhat similar evidence of sexual cycles attends many of the larger pulses in years prior to 1898.

This species affords a striking example of a perennial eulimnetic planktont. It is found in midwinter under the ice in water at the freezing point, and even under these conditions it multiplies, producing pulses whose amplitude surpasses that of many rotifers of the plankton, and runs a reproductive cycle similar to, though of less amplitude than, those at other seasons of the year. It shares with other organisms the vernal outburst, and repeats the process in summer months under maximum conditions of heat and in waters whose chemical condition is very different from that in which the hiemal and vernal pulses appeared. Successive generations of this species are thus adapted to widely different conditions. Through all the changes incident to ice, stagnation, flood, sewage pollution, changing temperature, the wax and wane and change of food, the constant and unceasing warfare of enemies which prey upon it and of parasites which plague it, and, above all and continuously, the removal of countless individuals from the place of their origin by the ceaseless current of the stream, this species lives on, holds its own in the plankton, and repeats year after year the same sequence of rhythmic pulses of occurrence in the river water. The secret of the process doubtless lies in its capacity to produce repeatedly these crops of winter eggs which serve to seed the environment and start anew the cycle of growth and reproduction whenever the favorable conditions prevail.

There is in this species no hard lorica whose variable processes might serve to demonstrate to every observer its capacity for variation. This is doubtless one of the reasons why we do not find a host of new species and varieties of *Polyarthra* as in the case of *Brachionus*. It is subject to considerable variation in size, and the swimming lamellæ vary in length, width, and serrations. Hempel ('99) records Wierzejski's var. *euryptera* in our plankton, and I have often observed it, but no record was kept of it since the characters which define it are not readily seen in plankton enumeration. Weber ('98) has mentioned, without designating by name, a long-spined variety which I find very common among the individuals which occur in the Illinois.

This planktont is subject to attacks of internal parasites (*Sporozoa?*) which infest it at the times of its maximum pulses, though never to the extent observed in the case of *Bimœrium* in *Brachionus*. It is very frequently loaded down by *Colacium*, and some of the smaller peritrichous *Ciliata* are often found upon it. The absence of a hard lorica has served to obscure somewhat its food relations to whatever animals prey upon it.

*Polyarthra platyptera* is a cosmopolite, and is apparently found generally in the fresh-water plankton. Jennings ('00) reports it as abundant in the waters of the Great Lakes, and it has been found generally in American waters. Zacharias ('98) and Marsson ('00) find it in pond and stream waters of Germany; Stenroos ('98) reports it as a predominant rotifer in the plankton and littoral regions of Finland waters; and Borge ('00) finds it in Swedish plankton. It has also been found to be an important constituent in the plankton of European streams. Skorikow ('96) finds that it is the most abundant rotifer in the summer plankton of the River Udy, constituting almost a third of the total rotifers. There are indications in his records of recurrent pulses, and the largest numbers are found in September. Zimmer ('99) finds it perennial in the Oder, but never abundant. Schorler ('00) finds it in the Elbe from April to September, with maximum in August. Lauterborn ('98a) lists this species among the perennial rotifers, and states that it is dicyclic in the Rhine and its adjacent waters, which he has examined quite thoroughly. The vernal sexual period begins with the appearance of the male eggs in March, and winter eggs follow in April and May. The second sexual period extends from the end of July to the end of October, with a maximum in September–October. This bears some resemblance to the distribution in the Illinois, with the exception that the recurrent cycles which make the species polycyclic were not noted, and that male or winter eggs were not present in the colder months. It may be that the application of the quantitative statistical method with brief intervals of collection in the Rhine would reveal a still closer correspondence in the seasonal routine of *Polyarthra* in the two streams. Wesenburg-Lund ('98) finds that temperature has nothing to do with the appearance of the sexual cycle of this species in Danish waters. Males were found in December, as also (eggs only) in the Illinois. He also found differences in different bodies of water as to the times of the sexual cycles. Apstein ('96) has found this species perennial and one of the most abundant rotifers in plankton of the lakes near Plön, Germany, with maximum period from April to August, and in November in one lake, and in July–August in another. The sexual cycle was noted in May–June only. Seligo ('00) finds the species perennial in lakes near Danzig, with large numbers in April and July. His collections were too widely separated to trace fully the seasonal fluctuations. Burckhardt ('00a) finds *Polyarthra* in small numbers in winter months in the plankton of Swiss lakes, and in larger numbers in the summer, but does not trace their seasonal fluctuations.

*Pterodina patina* Ehrbg.—Average number of females, 37. With two exceptions all the records of this species lie between the last of May and the first of October. There are but four records below 70°. This indicates optimum conditions for the species during the period of maximum heat, and further evidence of this lies in the occurrence of the larger numbers during this period. Appearances in January–March suggest a perennial habit; and small and irregular numbers, that the species is largely adventitions. Hempel ('99) also records *P. valvata* Hudson from Quiver Lake.

*Rattulus tigris* O. F. Müll.—Average number of females, 207. I have not found this species in any year later than October, though, as shown in Table I., it appears in January at minimum temperatures, and continues in small numbers and somewhat irregularly until autumn. These conditions and the absence of pulses suggest that the species is adventitious in the plankton. The greater part of the occurrences were recorded above 50° and the larger numbers above 60°, indicating an optimum during summer months. The record in Table I. refers to the species figured by Jennings ('00) under this name.

*Rattulus sulcatus* Jennings was found seven times in the plankton in July and August during maximum temperatures. It is probably adventitious in the plankton.

*Salpina brevispina* Ehrbg. was found September 5, 1895, at 74°, and April 29, 1896, at 70°.

*Salpina eustala* Gosse was found July 13, 1894, at 82°.

*Salpina macracantha* Gosse was found September 5, 1895, at 74°.

*Salpina ventralis* Ehrbg. was found July 29, 1895, at 75°. In common with other species of the genus it is adventitious in the plankton.

*Schizocerca diversicornis* v. Daday.—Average number of females, 46. The earliest record of this species was June 1, 1896, at 70°; and the latest, September 20, 1895, at 78°. Most of the records and the larger numbers are in July–September during the period of maximum heat, in which its optimum conditions must be found. Egg-bearing females were also found in these months. This species is closely related to the *Anuræa aculeata* group, and like it is exceedingly variable, especially in degree of development of the various spines. Variety *homoceros* Wierz. was found in May, June, and August, 1896. Five sixths of all the individuals recorded were found in 1896, and the fact that this was a year of unusually disturbed hydrograph (Pt. I., Pl. X.) suggests that this form may be to some extent adventitious in our plankton, but no direct relation to the access of flood waters can be traced.

Lauterborn ('98a) lists this species among the summer planktonts of the Rhine, and Seligo ('00) finds it in large numbers, with a maximum in July, in lakes near Danzig. Zacharias ('98) reports it in German pond plankton, Zimmer ('99) finds it in the Oder, and Schorler ('00) in the summer plankton of the Elbe.

*Synchæta pectinata* Ehrbg.—Average number of individuals, 3,950; of eggs, 13,823. It was much more abundant in previous years, averaging in 1897 23,227 and 28,230; in 1896, 7,064 and 7,927; in 1895, 13,071 and 4,730; in 1894, 7,520 and 1,659. The effect of the disturbed hydrograph of 1896 is seen in the smaller numbers of that year, while the larger numbers in 1897 may be attributed to the more stable conditions. The small numbers in 1898 do not seem to be correlated with any feature of the environment.

This species has been found in every month of the year, and is thus perennial in our plankton. As will be seen, however, in Table I., the most of the occurrences and a much greater proportion of the individuals are found between May and October, and thus above 60°. The same limitations are found in the other years, with the exception that in 1896 there was a more continuous and larger development from the last of February. In the table which follows it may be noted that all of the pulses but four are at temperatures above 70°, and of these four none exceeds 25,000, and two do not exceed 2,500. The optimum conditions for the species in our waters are therefore above 70°. The average temperature at the time of the larger pulses is near 80°. The vernal pulses are poorly defined, as are likewise the autumnal ones. It is a midsummer species in our waters, with its maximum in August.

PULSES OF SYNCHÆTA PECTINATA.

| Year | Date | Temp. | No. | Date | Temp. | No. | Date | Temp. | No. |
|---|---|---|---|---|---|---|---|---|---|
| 1894 | —— | —— | —— | —— | —— | —— | —— | —— | —— |
| 1895 | —— | —— | —— | —— | —— | —— | —— | —— | —— |
| 1896 | Mar. 3 | 35° | 6,360 | Apr. 10 | 46° | 24,436 | —— | —— | —— |
| 1897 | —— | —— | —— | —— | —— | —— | —— | | —— |
| 1898 | —— | —— | —— | Apr. 26 | 57° | 1,600 | June 21 | 77° | 112,000 |

| Year | Date | Temp. | No. | Date | Temp. | No. | Date | Temp. | No. |
|---|---|---|---|---|---|---|---|---|---|
| 1894 | July 13 | 83° | 74,606 | —— | —— | —— | —— | —— | —— |
| 1895 | July 23 | 80° | 1,749 | Aug. 12 | 85° | 175,230 | Sept. 12 | 79° | 27,740 |
| 1896 | July 10<br>" 28 | 80°<br>82° | 22,200<br>38,000 | Aug. 26 | 75° | 50,400 | —— | —— | —— |
| 1897 | —— | —— | —— | Aug. 10<br>" 24 | 81°<br>78° | 83,200<br>264,000 | —— | —— | —— |
| 1898 | July 19 | 84° | 20,800 | Aug. 2<br>" 23 | 78°<br>82° | 12,000<br>3,200 | Sept. 27 | 73° | 30,400 |
| 1898 | Dec. 13 | 33° | 2,500 | —— | —— | —— | —— | —— | —— |

Of the 18 pulses listed in the preceding table 17, fall within the limits of periods included in Plates I. and II. Of these 17 there are 7 which coincide with, and 9 which follow shortly after, the culmination of the pulses of the chlorophyll-bearing organisms, while 1, a small one in March, 1896, shows no such correlation. Food is thus a primary factor in the production of these recurrent pulses. As will be seen in Table I., these pulses uniformly coincide with those of the total *Ploima*, and a similar relation may be followed in prior years.

The eggs of this species are not usually carried by the female for any length of time, and are rarely found attached in preserved material. For this reason the sexual cycles are not easily followed with accuracy in the statistical data. It may be seen in Table I. that the free winter eggs belonging to both species of *Synchæta* are most numerous in the period of the larger pulses, and that their occurrences show some tendency to coincide with these pulses. Proof that these pulses terminate in sexual reproduction is thus lacking, though it seems probable from some of the evidence.

*Synchæta pectinata* has not been widely reported from American waters. Jennings ('94) finds it in Michigan and Kellicott ('97) in Lake Erie, but it has not been elsewhere reported in American plankton. It appears, however, in many European records. Skorikow ('96) finds it in the summer plankton of the River Udy, in Russia; Zimmer ('99) finds it in common with *S. tremula* in the Oder throughout the year. He makes the statements that it is never rare, is somewhat more abundant in the spring, and is, at other times, present "in relativ gleichmässiger Haufigkeit." In the light of our results it seems probable that the data at Zimmer's disposal were insufficient to justify his conclusions as to the uniformity of its seasonal distribution. Schorler ('00) finds it in the Elbe in April, May, and October, with a maximum in May. Lauterborn ('98a) finds it perennial in the plankton of the Rhine, and lists it among the dicyclic species with two periods of sexual reproduction, one in April and one from the end of July to October. Judging from the character of the statistical data which have been presented for this and other species in the Illinois it seems probable that the later period noted by Lauterborn may include several cycles, and that the species is usually a polycyclic one. Seligo ('00) reports it perennial in waters near Danzig, with largest numbers in April and

September. Apstein ('96) finds that this species (including *S. tremula* and *S. grandis*) is one of the most abundant in lakes near Plön, with variable maxima in different bodies of water. He finds it perennial in one case, and reports vernal maxima. Winter eggs were found in March and April.

*Synchæta stylata* Wierz.—Average number of individuals, 120,391; of eggs, 17,797. In 1897, 42,577 and 9,127; in 1896, 24,099 and 5,125; in 1895, 155,880 and 2,418; in 1894, 8,582 and 132. This species affords an exception to the general rule hitherto observed among the rotifers of our plankton in that it is more abundant in 1898 than in the previous year. As will be seen in the following table both the vernal and autumnal pulses are unusually large in 1898, while in the previous year the vernal pulse is only moderate and the autumnal pulse is scarcely to be detected. For some reason the prolonged low water and sewage contamination of the autumn of 1897 was not favorable to the usual growth of this species. It may be that it was crowded out by the unusual development of *Polyarthra* at that season (Pl. V.).

PULSES OF SYNCHÆTA STYLATA.

| Year | Date | Temp. | No. | Date | Temp. | No. | Date | Temp. | No. |
|---|---|---|---|---|---|---|---|---|---|
| 1894 | ——— | ——— | ——— | ——— | ——— | ——— | ——— | ——— | ——— |
| 1895 | ——— | ——— | ——— | ——— | ——— | ——— | ——— | ——— | ——— |
| 1896 | Jan. 6<br>" 25 | 32°<br>33° | 13,356<br>3,648 | ——— | ——— | ——— | ——— | ——— | ——— |
| 1897 | ——— | ——— | ——— | ——— | ——— | ——— | ——— | ——— | ——— |
| 1898 | Jan. 25 | 32° | 4,257 | ——— | ——— | ——— | Mar. 1<br>" 22 | 33°<br>51° | 6,400<br>58,000 |
| 1899 | Jan. 14 | 34° | 12,000 | Feb. 14 | 32° | 19,200 | Mar. 21 | 37° | 5,600 |

| Year | Date | Temp. | No. | Date | Temp. | No. | Date | Temp. | No. |
|---|---|---|---|---|---|---|---|---|---|
| 1894 | ——— | ——— | ——— | ——— | ——— | ——— | ——— | ——— | ——— |
| 1895 | Apr. 29 | 64° | 219,123 | ——— | ——— | ——— | ——— | ——— | ——— |
| 1896 | Apr. 29 | 70° | 380,586 | May 25 | 75° | 10,800 | June 17 | 76° | 79,200 |
| 1897 | ——— | ——— | ——— | May 25 | 66° | 643,680 | ——— | ——— | ——— |
| 1898 | ——— | ——— | ——— | May 3<br>" 31 | 60°<br>70° | 1,139,000<br>61,600 | June 21 | 77° | 795,200 |

PULSES OF SYNCHÆTA STYLATA—*continued.*

| Year | Date | Temp. | No. | Date | Temp. | No. | Date | Temp. | No. |
|---|---|---|---|---|---|---|---|---|---|
| 1894 | ——— | —— | ——— | ——— | —— | ——— | ——— | —— | ——— |
| 1895 | ——— | —— | ——— | Aug. 1 | 79° | 10,287 | Sept. 27 | 73° | 12,225 |
| 1896 | ——— | —— | ——— | Aug. 8 | 86° | 8,400 | ——— | —— | ——— |
| 1897 | July 21 | 81° | 103,200 | ——— | —— | ——— | Sept. 7 | 80° | 28,000 |
| 1898 | July 19 | 84° | 64,800 | Aug. 2<br>" 23 | 79°<br>82° | 170,400<br>24,800 | Sept. 27 | 73° | 265,600 |

| Year | Date | Temp. | No. | Date | Temp. | No. | Date | Temp. | No. |
|---|---|---|---|---|---|---|---|---|---|
| 1894 | Oct. 17 | 58° | 63,935 | ——— | —— | ——— | ——— | —— | ——— |
| 1895 | ——— | —— | ——— | Nov. 27 | 33° | 901,901 | Dec. 11 | 32° | 1,121,056 |
| 1896 | ——— | —— | ——— | Nov. 17 | 44° | 114,000 | ——— | —— | ——— |
| 1897 | Oct. 5<br>" 19 | 71°<br>65° | 12,000<br>15,800 | Nov. 9<br>" 30 | 50°<br>34.5° | 26,400<br>87,200 | Dec. 14 | 36° | 72,200 |
| 1898 | Oct. 25 | 49° | 824,500 | Nov. 15 | 41° | 110,000 | Dec. 6<br>" 20 | 34°<br>33° | 42,500<br>59,200 |

This is the most abundant of all the rotifers in our plankton, exceeding by 30 per cent. *Polyarthra*, the next in abundance. It constituted one fifth of the total *Ploima* in 1898, and is accordingly a large factor quantitatively and ecologically in the economy of the plankton of the Illinois River.

It is a perennial planktont, occurring in six sevenths of our collections and usually in considerable numbers. The distribution in 1898 (Table I.) is a fair index of the usual seasonal routine, with the exception that in all prior years the July–August minimum is more pronounced and better sustained. The development in January–February is never large, rarely exceeding 20,000. In March, numbers rise rapidly, usually with a minor pulse, the recovery from which in April culminates in a vernal pulse, which in three of the six years was the largest of the year. Following this vernal pulse there is a series of smaller pulses throughout the summer. The decline of the June flood, when this occurs, seems to offer favorable conditions (*cf.* foregoing table and Pt. I., Pl. IX.–XII.) for the development of a pulse which is but little smaller than the vernal one. It may be of some significance that this pulse and the vernal one both occur on the decline of the major floods of the year, and that the relative proportions of the two floods are to some degree paralleled by the amplitude of the pulses of *Synchæta* which attend their decline. The effect of the impounding backwaters as reservoirs for the greater development of the plankton is suggested by these data.

Following the midsummer minimum is an autumnal pulse whose amplitude and location alike are subject to much variation. As will be seen in the table on pages 213 and 214, the maximum autumnal pulse is located twice in October, twice in November, and once in December. This may be due to the fact that the collections are insufficient in some of the years, or to the probability that any one of several recurrent autumnal pulses may be the major pulse of that season.

An examination of the seasonal distribution in 1898 (Table I.) and of the location and temperatures of the pulses recorded in the table on pages 213 and 214 will suffice to demonstrate the capacity of this species to develop at all temperatures within the seasonal range. The largest pulse (1,139,000 on May 3, 1898) is at 60°, and the next in size (1,121,056 on December 11, 1895) is at 32°. It will, however, be seen in the two tables that the pulses and the numbers in general during the periods of maximum heat and cold are not so large as in the intervals of more moderate temperatures. The impetus of the autumnal development may carry some of the pulses over in to minimum temperatures, but the level of development declines thereafter. There is thus something of a tendency for the average temperature of the larger occurrences to approach the average temperature of the year.

The number of pulses listed in the table on pages 213 and 214 is 38. Of these, 34 fall within the period included in Plates I. and II. of the pulses of chlorophyll-bearing organisms. Of the 34 there are 18 which coincide in location with these plant pulses, 12 which follow at a brief interval, and 4 which bear no such relation, three of the last being minor winter pulses.

The dependence of the recurrent periods of rapid multiplication of *Synchæta*—the most abundant rotifer of the plankton—upon the rhythmic increase of the food supply is thus fairly demonstrated. The coincidence of the pulses of *Synchæta* with those of the total *Ploima* is readily seen in Table I., and is equally apparent in prior years.

Eggs of this species are not carried by the parent for any length of time, so that reproductive cycles are not easily traced. The total number of the summer eggs of *Synchæta* will be found (Table I.) to fluctuate somewhat with the pulses of the species. The free winter eggs, belonging probably to both species of *Synchæta*, also show some tendency to predominate at and after the culmination (Table I.) of the pulses. A female carrying a male egg was recorded during the rise of the spring pulse in 1898, and attached winter eggs were noted at the vernal pulse in 1895 and 1897. The evidence points toward the culmination of these pulses in a sexual cycle.

The soft and flexible nature of this rotifer and the absence of spinous outgrowths have made whatever variability the species possesses less evident than it is in such a genus as *Brachionus*. There is considerable variation in size—possibly due to age—even in the same collection. The determination of preserved material of this genus is fraught with insuperable difficulty. The separation of *pectinata* and *stylata* in our records is at the best only probable. It may be that other species of *Synchæta* have been included with the individuals referred to *stylata*. In any event the result of the division has led to symmetrical results comparable with those of other planktonts. *Synchæta* is often parasitized at the times of the larger pulses by some sporozoan (?). At the maximum of the vernal pulse in 1898 over 4 per cent. of the individuals were thus affected, the infestation continuing through the decline of the pulse. External parasites, *Colacium* and *Rhabdostyla*, are rare.

This species has not been found widely in the plankton, possibly because of the confusion of *stylata*, *tremula*, and *pectinata* in identification. From the large numbers reported in almost every instance where it has been found, the expectation of its wide-spread occurrence is at least raised, waiving in this connection the possibility of specific confusion. Jennings ('94) found it to be very abundant in towings in Lake St. Clair, and ('96) in Lake Michigan near Charlevoix. He finds it less abundant in the summer plankton of Lake Erie ('00). Stenroos ('98) reports it as one of the most abundant limnetic rotifers in Lake Nurmijärvi in Finland in the summer, and Skorikow ('97) finds that next to *Polyarthra* it is the most abundant rotifer in summer months in the River Udy near Charkow, Russia. His figures of occurrence show some traces of recurrent cycles in these months, with maximum numbers at the first of August. Lauterborn ('98a) lists it among the summer rotifers of the plankton of the Rhine. The genus is in need of a thorough revision in the light of possible variation.*

*Taphrocampa annulosa* Gosse.—Average number, 71. Found in September, at 73°. Evidently adventitious.

*Triarthra longiseta* Ehrbg.—Average number of individuals, 3,147; of eggs, 293. This species was about twice as abundant in the stable conditions of 1897, and was present in less than half these numbers in the recurrent floods of 1896.

It is a perennial species, having occurred in every month of the year. The continuous occurrences and the larger numbers lie in all years between May and October and above 60°. In 1898, only about 3 per cent. of the total individuals were found below this temperature. With the exception of the vernal pulse of 1898 all of the larger numbers were found in the period of maximum heat. The optimum conditions for this species are thus found within that period and above 70°.

The seasonal routine of the species is varied somewhat from year to year. There is usually a slight vernal pulse—larger than usual in 1898—and this is followed by recurrent pulses throughout the summer. The season closes without a predominant autumnal pulse, and after September the numbers fall and the occurrences become sporadic until the following April.

The pulses of this species are listed in the following table, which gives their locations and temperatures.

Of the 21 pulses recorded, 18 are within the periods of the plant pulses shown in Plates I. and II. Of these 18 there are 8 which coincide with these plant pulses, 9 which follow after a short interval, and 1 which shows no such relation. The dependence of the pulses of *Triarthra* upon food conditions is suggested. The pulses of *Triarthra* will be found on examination of Table I. to coincide in 1898 in the main with those of the total *Ploima*.

The pulses are never very large, and the evidences of reproduction are not well defined. Attached summer eggs attend the larger pulses, and free winter eggs of the species were found in October–November in 1898. In previous years free or attached eggs attended vernal or summer pulses at times. The evidence indicates a polycyclic habit.

* See Rousselet, '02.

PULSES OF TRIARTHRA LONGISETA.

| Year | Date | Temp. | No. | Date | Temp. | No. | Date | Temp. | No. |
|---|---|---|---|---|---|---|---|---|---|
| 1894 | —— | —— | —— | —— | —— | —— | —— | —— | —— |
| 1895 | Apr. 29 | 64° | 2,332 | —— | —— | —— | —— | —— | —— |
| 1896 | Apr. 29 | 70° | 5,556 | —— | —— | —— | June 11<br>" 27 | 73°<br>80° | 4,000<br>6,000 |
| 1897 | —— | —— | —— | May 25 | 66° | 8,800 | —— | —— | —— |
| 1898 | —— | —— | —— | May 10<br>" 31 | 62°<br>70° | 38,400<br>1,000 | June 28 | 78° | 800 |

| Year | Date | Temp. | No. | Date | Temp. | No. | Date | Temp. | No. |
|---|---|---|---|---|---|---|---|---|---|
| 1894 | —— | —— | —— | Aug. 15 | 84° | 1,337 | —— | —— | —— |
| 1895 | July 18 | 80° | 19,080 | Aug. 21 | 82° | 10,683 | Sept. 12 | 79° | 2,336 |
| 1896 | July 6 | 80° | 2,800 | Aug. 8 | 86° | 7,200 | —— | —— | —— |
| 1897 | July 21 | 81° | 49,600 | Aug. 17 | 79° | 9,600 | Sept. 7 | 80° | 70,000 |
| 1897 | Oct. 5 | 71° | 8,000 | —— | —— | —— | —— | —— | —— |
| 1898 | July 26 | 89° | 28,000 | Aug. 30 | 83° | 6,400 | Sept. 27 | 73° | 14,400 |

This is an exceedingly variable species. It varies in the relative length of the three long setæ, in their spinosity, and in the location of the posterior one. Many of the individuals in our waters resemble the form described by Plate ('85) as *T. terminalis*. The long-spined form described by Zacharias ('94) as var. *limnetica* is also abundant. It is doubtful if either form is worthy even of varietal distinction.

This species has been reported only from Lake Erie and the Illinois River in this country, and seems to be rare in the former. Weber ('98) finds it abundant in the plankton of Lake Leman; Burckhardt ('00 and '00a) reports it as wide-spread and almost perennial in Swiss lakes, but with its maximum in December–February, and slight development during warmer months. Borge ('00) finds it to be one of the common rotifers in the summer plankton in Sweden; Marsson ('00) reports its perennial seasonal range in several German waters, with greater numbers during the warmer season. Apstein ('96) gives it a perennial distribution in Lake Plön, with larger numbers in June–November, and maximum in June–July or August. According to Seligo ('00) the species is perennial in lakes near Danzig, rivaling *Polyarthra* in abundance, and exhibiting maxima in the warmer months from April to October.

It is also a member of the potamoplankton of European streams. Skorikow ('97) finds it in summer months in the Udy, and Zimmer ('99) reports it as present in small numbers and irregularly in the Oder from April to November. Schorler ('00) finds it in the Elbe in May–October with maxima in May and September, and Lauterborn ('98a) includes it in his list of perennial rotifers in the plankton of the Rhine. It has two sexual periods, the first in March–May and the second in July–October, and he suggests the probability of a polycyclic habit in some waters.

*Trochosphæra solstitialis* Thorpe was found June 27, July 2, and August 15, in 1896; in 1897, on May 25 and July 14–30. Free winter eggs were taken August 15, 1896. All occurrences were above 66°. These records were all from plankton taken in mid-channel of the main stream. *Trochosphæra* was found in greatest abundance at the outlet of Flag Lake (Pt. I., Pl. II.) in July, reaching 9,664 per m.[3] at 72°. It was also found in August in the weedy backwaters of Dogfish Lake. Both of these backwaters connect with the river (Pt. I., Pl. II.) below the point at which our collections were made. It was either introduced from some similar backwater higher up the stream than our plankton station, or developed in the river itself.

### SCIRTOPODA.

This order is represented in the plankton by a single species, whose discussion will suffice for the order.

*Pedalion mirum* Huds. Average number, 4,524. This is a summer planktont of somewhat definite temperature limits. The following table combined with the data in Table I. will suffice to characterize its seasonal fluctuations.

Its limitation to temperatures above 60°, indeed almost 70°, is apparent. There are in all but two records below 60°, and but four below 70°. It is a typical midsummer planktont, with several recurrent pulses during the period of maximum temperatures.

The location of these pulses with reference to those of the chlorophyll-bearing organisms is significant. As shown in Table I., they follow immediately, or coincide with, those of the synthetic organisms. For example, the apices of the pulses of *Mastigophora*,

| Year | First record | | First maximum | | |
|---|---|---|---|---|---|
| | Date | Temp. | Date | Temp. | No. |
| 1894 | ——— | —— | June 29 | 83° | 2,592 |
| 1895 | ——— | —— | July 6 | 80° | 330,932 |
| 1896 | May 25 | 70° | July 28 | 80° | 20,000 |
| 1897 | June 28 | 75° | July 21 | 84° | 80,000 |
| 1898 | June 21 | 77° | July 26 | 89° | 99,600 |

| Year | Second maximum | | | Last record | |
|---|---|---|---|---|---|
| | Date | Temp. | No. | Date | Temp. |
| 1894 | ——— | —— | ——— | Sept. 17 | 72° |
| 1895 | Aug. 21 | 81° | 3,561 | Oct. 2 | 63° |
| 1896 | Aug. 15 | 81° | 77,600 | Sept. 16 | 71° |
| 1897 | Aug. 17 | 79° | 79,200 | Sept. 14 | 73° |
| 1898 | Aug. 16 | 77° | 22,400 | Nov. 1 | 45° |

*Bacillariaceæ*, and *Chlorophyceæ* in the period in question in 1898 are (Pl. II.) July 19, August 9, August 30, and September 27. The apices of the *Pedalion* pulses are July 26, August 16, and September 27, the last coinciding with the pulse of chlorophyll-bearing organisms. In 1897, the intercalation of the two pulses is apparent, and in 1896, two out of three pulses are intercalated and a third is coincident. As will be seen in Table I., these pulses of 1898 are approximately coincident in many cases with those of other rotifers—*Synchæta*, *Polyarthra*, *Triarthra*, and *Brachionus*. The significance of this intercalation lies probably in the food relations of the two groups of organisms.

Females with a single egg attached to the body have been noted at the times of the maxima of the pulses, or immediately thereafter, in five instances. On the pulse of July 26, 1898, a female with four male eggs was found.

This species was not reported by Apstein ('96) from the lakes of Holstein, but was found by Lauterborn ('98a) in the Rhine and its backwaters. Here also it was a summer form, appearing about the middle of June, with a maximum in August or September and disappearing late in October, conditions of distribution much resembling those in the Illinois. It is regarded, along with other summer forms, as monocyclic. The appearance in our waters of male eggs July 26, at the height of the first pulse, leads to the inference that there may be several cycles; for example, three in 1898, with the recurrent pulses, in a single summer season. Weber ('98) gives it as a summer rotifer in Switzerland, and Skorikow ('97) finds it in July–September in the Udy River, in Russia; but it is not reported from the Oder by Zimmer ('99), nor from the Elbe by Schorler ('00). Kellicott ('97) finds it in Lake Erie in small numbers in the summer.

In addition to the species of rotifers noticed above, Hempel ('99) has reported the following in the Illinois River or its backwaters: *Floscularia ornata* Ehrbg., *Limnias ceratophylli* Schrank, *Cephalosiphon limnias* Ehrbg., *Œcistes intermedius* Davis, *O. mucicola* Kell., *Pedetes saltator* Gosse, *Furcularia forficula* Ehrbg., *F. longiseta* Ehrbg., *Eosphora aurita* Ehrbg., *Diglena grandis* Ehrbg., *D. catellina* Ehrbg., *D. biraphis* Gosse, *Cœlopus tenuior* Gosse, *Scaridium longicaudum* Ehrbg., *Distyla gissensis* Eckstein, *D. ohioensis* Herrick, *D. stokesi* Pell, and *D. hornemanni* Ehrbg.

## GASTROTRICHA.

*Chætonotus* sp. occurred singly in the plankton August 29, 1896, July 30, 1897, and February 15, 1898, with a temperature range of 32.5° to 84°.

## ENTOMOSTRACA.

Average number, 47,042. In 1897, a more stable year, 91,050; in 1896, a year of disturbed hydrograph, 50,158; in 1895, in more stable conditions, 148,348. The *Entomostraca* appear in every collection at all seasons of the year. The decline to the winter minimum occurs in November–December. Numbers are at a minimum (generally less than 5,000 per m.$^3$) in midwinter (January–February); rise in March to about 25,000 per m.$^3$; and attain the maximum for the year in a vernal pulse of 200,000 to 1,500,000 in April–May. Following this, there is frequently a second pulse of large proportions in June, which in 1898 exceeds (Table I.) that of May. During the remainder of the year there is usually a series of recurrent pulses, of declining amplitude in 1896 and 1898, but rising to unusual heights (618,750 on September 9) in the stable conditions of 1897. In the main the pulses of *Entomostraca* coincide with or approximate to the location of those of the other organisms of the plankton, and often show correlations in amplitude.

### BRANCHIOPODA.

*Eubranchipus serratus* Forbes. Young branchiopod larvæ questionably referred to this species appeared in the plankton in January–March, 1899, in small numbers at minimum temperatures.

### CLADOCERA.

Average number, 6,068 per m.$^3$ In 1897 they were more abundant, averaging 17,863 per m.$^3$ in the more stable conditions of that year. In 1896, a year of recurrent floods, numbers fell to 7,719, while in 1895, a year of low water in spring, when many of the *Cladocera* attain their maximum, the greatest average, 31,937, was recorded. The phenomenal number of 443,716 per m.$^3$ appeared on June 19 in the stable low water (1.80 ft.) then prevailing. In 1894, another year of low levels, the annual average was also large (23,952), though probably enhanced by the fact that collections were not made in flood waters in this year.

The *Cladocera* appear in all but 10 of the 182 collections enumerated, the ten exceptions falling in November (1), January (2), February (6), and April (1), and usually in flood waters or, as in 1895, in stagnation conditions under the ice. Although the *Cladocera* occur in all months of the year, they nevertheless, as a group, exhibit decided temperature adaptations, as appears from the fact that *all records in excess* of 4,000 per m.$^3$ fall between May 1 and September 1 with but 6 exceptions,—4 in the phenomenally early spring of 1896, and 2 in the delayed high temperature of October, 1897.

The minimum records (less than 500 per m.³) are found during minimum temperatures. The numbers increase slightly (generally less than 2,000) as temperatures rise in March–April, rise abruptly, as they approach or pass 70°, to a vernal maximum in May–June, and decline during midsummer excepting when unusual pulses of *Moina* or *Diaphanosoma* raise the level of the pulse maxima above 25,000. This decline continues in channel plankton through the autumn until the low level of approximately 2,000 per m.³, at the most, is again attained in October, and falls irregularly to 500, or less, as minimum winter temperatures arrive in December. Exceptions appear in 1897, when a well-defined autumnal pulse of large amplitude (193,500) is found on September 14, and is followed by others of declining amplitudes (137,600, October 5; 5,520, November 15; 4,240, December 14) during stable autumnal conditions.

All of the records above 4,000 per m.³, with one exception, are found at temperatures above 45°, and all in excess of 8,000, with 4 exceptions, after the vernal rise in temperature passes 70° in April–May, and before the autumnal decline reaches this point in September. The *Cladocera* are thus planktonts of the warmer channel-waters.

The relation which hydrographic conditions bear to the seasonal occurrences of *Cladocera* is apparent in the yearly averages above quoted, and appears still more clearly in a comparison of the cladoceran population and movement in river levels in July–December, 1897 and 1898, as given below.

| | July | | August | | Sept. | | Oct. | | Nov. | | Dec. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Average No. *Cladocera* per m.³ | 1897 | 1898 | 1897 | 1898 | 1897 | 1898 | 1897 | 1898 | 1897 | 1898 | 1897 | 1898 |
| | 12720 | 3050 | 13960 | 3756 | 70675 | 1700 | 40350 | 1615 | 2532 | 620 | 1945 | 236 |
| Total movement in river levels, in ft. | 5.2 | 7.4 | 2.6 | 7.5 | 0.6 | 6.2 | 0.6 | 3.9 | 2.2 | 2.6 | 0.5 | 2.4 |

Hydrographic changes affect the *Cladocera* by increasing the amount of silt and flocculent debris in suspension, which, by adherence to the swimming antennæ and flotation processes of the animal, tend to impede its movements and sink it to the bottom, where it is removed from its normal feeding area and readily becomes the prey of the larger organisms of the bottom fauna. Barren flood waters also tend to displace and wash away in the increased current the *Cladocera* which have developed in the stream, and to afford both less food and less time for their further development.

The occurrences of the total *Cladocera* fall into the type of recurrent pulses, though with slightly less distinctness than in the case of individual species of the group. Such pulses can be traced in all seasons in which records were made at short intervals, and suggestions of their occurrence appear in the less frequent records of other seasons. Thus in July–December, 1897, (Pl. IV.), there are 6 well-defined pulses culminating at intervals of 3(1), 4(2), 5(1), and 6(1) weeks. In 1898 (Table I.) the pulses are less regular in the flood waters of the disturbed year. In 1896, when records were frequent, we can trace pulses in March, May, June, July, August, and September. The character of these pulses is well illustrated in the vernal pulse of 1898 (Table I. and Pl. IV.), culminating June 7 at 136,000. The species which share in this pulse are *Alona affinis*, *A. costata*, *A. quadrangularis*, *Bosmina longirostris**, *Ceriodaphnia scitula**, *Chydorus sphæricus**, *Daphnia hyalina**, *D. cucullata**, *Diaphanosoma brachyurum*, *Leptodora hyalina*, *Macrothrix laticornis*, *Moina micrura*, *Pleuroxus denticulatus*, *Scapholeberis mucronata*, and *Simocephalus serrulatus*. Of these, only the five marked by the asterisk occur in numbers sufficient by our methods to delineate a pulse. The other species are accordingly of little consequence in modifying the form or location of the pulse. The June volumetric pulse (Part I., Pl. XII.) culminates June 14 at 6.99 $cm.^3$ per $m.^3$, though the record for June 7 is also high (5.28). The cladoceran pulse culminates June 7 at 136,000. On this same day four of the dominant species also reach their culmination, viz.: *Bosmina longirostris* (62,800), *Ceriodaphnia scitula* (55,800), *Daphnia cucullata* (3,400), and *D. hyalina* (11,600), the remaining 2,400 being contributed by other species. *Chydorus sphæricus*, which appears this spring only in small numbers, attains its maximum (7,880) on May 24, two weeks earlier, though the record for May 31 is also high

(5,040), indicating a probable maximum between these dates. In other seasons, for example in 1896 and 1897, the maxima of this species coincide generally with those of other *Cladocera*, so that this divergence seems to be anomalous. An inspection of the table of records for 1898 gives a remarkably uniform and coincident rise and decline of the pulses of the several species which constitute this characteristic vernal pulse.

No effort has been made by me to determine the total cladoceran fauna of the Illinois River. Only those species are here given which have appeared in our plankton enumeration. A number of others are known to occur in the littoral fauna, and a few scattering individuals found in the plankton were not identified.

Of the 25 forms here listed, only 10—named in the sequence of their relative numbers as shown in grand totals—may be regarded as typical planktonts, autolimnetic in channel plankton, viz.: *Moina micrura*, *Bosmina longirostris*, *Daphnia cucullata* and vars. *apicata* and *kahlbergiensis*, *D. hyalina*, *Ceriodaphnia scitula*, *Chydorus sphæricus*, *Diaphanosoma brachyurum*, and *Leptodora hyalina*. Of the ten, the last named and the varieties of *D. cucullata* appear to be of little quantitative importance in the channel plankton, though it may be that our methods of collection fail adequately to represent *Leptodora*. Of the remaining 15 species, *Alona affinis*, *Ceriodaphnia reticulata* and *C. rotunda*, *Scapholeberis mucronata*, and the two species of *Simocephalus* are the only adventitious *Cladocera* of quantitative importance, and this only to a relatively small extent.

### DISCUSSION OF SPECIES OF CLADOCERA.

*Alona affinis* Leydig.—Average number, 36. This species has a well-defined seasonal distribution. It appears in autumn in the last of October, as temperatures approach 40°, and remains until the end of June, when the summer maximum of 80° is re-established. The numbers are too small (Table I.) and irregular to define its seasonal fluctuations, though there are suggestions in the records of late autumnal and of vernal pulses. Egg-bearing females were recorded in January–February at minimum temperatures. No close dependence on hydrographic fluctuations is apparent to account for their occurrence in the plankton.

*Alona costata* Sars.—Average number, 11. Only a few scattered occurrences of small numbers. Earliest autumnal record, November 22, at 40°; latest vernal, May 24, at 73°.

*Alona quadrangularis* O. F. Müll.—Average number, 5. A few scattered occurrences in March–May.

*Alona* spp.—It is probable that some of the foregoing species of *Alona* are here included. There are 16 occurrences, scattered through all months but January, April, and November, with no large numbers and no marked seasonal distribution.

*Bosmina longirostris* O. F. Müll.—Average number, 2,441, of which 1,527 are adult females without large embryos, 390 with them, and 524 immature.

I include in this species *B. cornuta* Jurine, for I am unable to find any constant line of demarcation between these forms. The *longirostris* form is the dominant one in the channel plankton, the *cornuta* form being relatively rare.

*Bosmina* is a perennial planktont in our channel plankton, but occurs in small numbers only in October–May, no record in this period with the exception of that of October 5, 1897 (20,400), at 71°, exceeding 5,000 per m.$^3$, and most of them falling below 2,000. The records in November–March, with the exception of November–December, 1897, all fall below 1,000 per m.$^3$ In like manner the percentage of collections containing *Bosmina* in December–April is lower than that in the summer, the percentages being 64, 16, 26, 47, and 55 per cent. respectively for these colder months, and averaging 82 per cent. for the rest of the year. The percentage of occurrences in October–November remains high (82 and 81 per cent.), though the numbers per m.$^3$ fall off greatly.

The usual seasonal distribution is as follows: In January–March the occurrences are scattered and irregular and the numbers very small—less than 500 per m.$^3$ Toward the close of April the vernal increase makes its appearance, continues slowly through May, rarely attaining more than 5,000 per m.$^3$, and at the end of this month or early in June reaches the maximum development of the year in a vernal pulse of 40,320 (1896) or 62,800 (1898) per m.$^3$ From this summit there is an abrupt descent in a period of exhaustion to a level of less than 2,000 per m.$^3$ in the last fortnight of June. During the remainder of the year there appears a series of recurrent pulses of less magnitude, exceeding 10,000 per m.$^3$ in but three instances. These follow at intervals of four to six weeks. In July–September the amplitude of these pulses exceeds in all cases 5,000 per m.$^3$ In October (with the exception of 1897, when temperatures were unusually high), they decline in amplitude, and in November–December often fail to appear in the small numbers recorded. In 1894, records are too scanty to be of significance. In 1895 there are three well-defined pulses, and traces of a fourth in August–November. In 1896 there are five in May–September. In 1897 there are six in July–December, data during the remainder of the year being insufficient to define the pulses. In 1898 the vernal pulse in June and a feeble one in October are the only ones which appear. The pulses of *Bosmina* are best defined in the stable low water of the last six months of 1897. During that period they closely approximate in location of maxima and minima the quantitative pulses and those of the chlorophyll-bearing organisms and of the rotifers. (Compare on this point the plates for 1897 in Part I.—Kofoid, '03—and Pl. III. and IV.). The slopes of the pulses indicate that *Bosmina* is capable of very rapid multiplication; and their coincidence with other pulses just noted, taken in conjunction with the fact that males and ephippial eggs appear but rarely, suggests that these pulses of *Bosmina* are immediately dependent, in large part, upon fluctuations in the food supply for their origin and for the varying courses which they run.

The relations of *Bosmina* to temperature appear in the facts that all pulses exceeding 5,000 per $m.^3$ in amplitude occur at temperatures above 70°, that the vernal rise does not proceed with any rapidity until this temperature is attained, and that the depressing effect of the autumnal decline below 70° is at once apparent in the reduced numbers per $m.^3$ No constant relation between the pulses of *Bosmina* and the midsummer heat pulses—such as appears in the records of *Diaphanosoma*—can be traced in the occurrences of *Bosmina*.

An inspection of the accompanying table, in which the mean monthly *Bosmina* population per $m.^3$ of channel water in July–December, 1897 and 1898, is given, and also the total + and – movement in river levels for these months in each year, will suggest an intimate connection between stability of hydrographic conditions and the increase of *Bosmina*. In 1897 the total movement for these months is from five sevenths to one tenth of that in 1898, and in every instance the *Bosmina* population is also greater by from 7.5 to nearly 400-fold in 1897, the more stable year. The means of the six months are 2.03 ft. and a population of 3,691 in 1897 to 5.3 ft. and

BOSMINA AND HYDROGRAPHIC FLUCTUATIONS.*

| Year | July | | August | | September | |
|---|---|---|---|---|---|---|
| | Total movement, in feet | *Bosmina* per m.³ | Total movement, in feet | *Bosmina* per m.³ | Total movement, in feet | *Bosmina* per m.³ |
| 1897 | 5 {−3.9, +1.1} | 6,213 | 2.6 {−2.6, +0} | 3,973 | .6 {− .2, + .4} | 3,022 |
| 1898 | 7 {−6.9, + .1} | 140 | 7.7 {−3.3, +4.4} | 10 | 6 {−2.6, +3.4} | 15 |

| Year | October | | November | | December | |
|---|---|---|---|---|---|---|
| | Total movement, in feet | *Bosmina* per m.³ | Total movement, in feet | *Bosmina* per m.³ | Total movement, in feet | *Bosmina* per m ³ |
| 1897 | .6 {− .1, + .5} | 5,875 | 2.2 {− .7, +1.5} | 1,680 | 1.2 {− .6, + .6} | 1,585 |
| 1898 | 3.9 {−1.1, +2.8} | 780 | 3.2 {− .6, +2.6} | 32 | 3.8 {−2.8, +1.0} | 60 |

* + = rising levels; − = falling levels.

173 *Bosmina* in 1898. It is also true that months in which the disparity in stability is greatest are those in which the *Bosmina* ratios are greatest, and vice versa. It seems very probable that the increased current, the lessened time for breeding, and the greater burden of silt in flood conditions, especially rising waters, do not conduce to the rapid increase of *Bosmina* in channel plankton.

The effect of the high temperatures of the late autumn of 1897 is apparent in the amplitude of the October, November, and December pulses (20,400, 3,440, and 3,440, respectively), which exceed those of all other years at this season. Temperature thus plays—perhaps by virtue of its relation to the food supply—an important part in the seasonal delimitation of the amplitude of *Bosmina* pulses.

The *Bosmina* population in the plankton consists largely of parthenogenetic females. Males and females with ephippial eggs, were recorded only in October–December, 1897, and then only in small numbers and isolated occurrences. Females with eggs or embryos and the free young were found at all seasons of the year and at all temperatures, but most abundantly at the time of the pulses. Parasitized or fungused individuals are also found occasionally at these seasons of greatest numbers, and the high mortality following a pulse is evidenced by the large number of dead occurring in the plankton. The proportions of females, females with eggs or embryos, young, and dead during the May–June pulse of 1898, may be traced in the following records.

BOSMINA PER M.³, MAY–JUNE, 1898.

| Date | Females | Females with eggs | Young | Total living | Dead |
|---|---|---|---|---|---|
| Apr. 26....... | 800 | 0 | 0 | 800 | 0 |
| May 3....... | 1,600 | 400 | 800 | 2,800 | 0 |
| " 10....... | 1,600 | 1,000 | 1,000 | 3,600 | 400 |
| " 17....... | 1,300 | 1,100 | 1,100 | 3,500 | 100 |
| " 24....... | 3,280 | 1,400 | 1,240 | 5,920 | 920 |
| " 31....... | 25,120 | 2,000 | 6,800 | 33,920 | 1,280 |
| June 7....... | 38,800 | 9,200 | 14,800 | 62,800 | 9,200 |
| " 14....... | 2,200 | 3,000 | 800 | 6,000 | 1,400 |
| " 21....... | 1,000 | 500 | 0 | 1,500 | 100 |
| " 28....... | 300 | 200 | 200 | 700 | 100 |

*Bosmina longirostris* has been frequently reported in the plankton of European lakes. Apstein ('96) finds it perennial in Plönersee with larger numbers in June–September and a maximum in July. No pulse-like recurrence is noted, parthenogenesis prevails, and males and ephippia are rare. His results, save in the matter of pulses, are thus in general accord with ours. Stingelin ('97) notes great seasonal polymorphism in *B. cornuta* near Basel. Zacharias ('97a and '98b) records it in the plankton of German carp ponds.

Stenroos ('97 and '98) finds it in waters of Finland and Karelia, where the *cornuta* type is littoral, and a limnetic form, distinguished by him as *forma vernalis*, is abundant in the plankton in May. Scourfield ('98) finds it common in the waters of Epping Forest, where it is perennial, males and ephippia appearing only in September–November. According to Scott ('99) it appears at various seasons in the lochs of Scotland in both the littoral and limnetic fauna. Burckhardt ('00a) gives an extensive revision of the genus *Bosmina*, and includes in the *B. longirostris* group nine other so-called species, among which are *B. cornuta* Jur. The species is "pelagic or hemipelagic" in various Swiss lakes, though apparently not in numbers. The genus is there represented in the plankton principally by the *B. coregoni* group. Amberg ('00) lists it from Katzensee, near Zurich, as a perennial planktont with large numbers in May, August, and February, but gives no statistical data. Fuhrmann ('00) finds *Bosmina* perennial in Neuenburgersee, and *B. longirostris* with a maximum in May. Marsson ('00) finds *B.* "*longirostris-cornuta*" in lakes about Berlin throughout the year, with larger numbers in some lakes during the warmer months and in others in November–December. In Barlewitzersee, near Danzig, Seligo ('00) reports *B. cornuta* as perennial, with maxima in June and in October–November, the latter being the greater. Larger numbers appear in summer than in winter. Cohn ('03), in waters near Königsberg, finds *B. longirostris* only sparingly present, appearing in May–September with a maximum in July.

In European streams, also, *B. longirostris* is widely distributed. Lauterborn ('94) finds it abundant in the winter fauna of the Rhine. He also states that it is not acyclic in the backwaters, where he has found in three successive years both males and ephippia in May–June and again in November. There is thus a suggestion of a vernal and an autumnal pulse in these waters. Zimmer ('99) finds it throughout the whole year in the Oder. Schorler ('00) reports it from the Elbe at Dresden in May–October, with larger numbers in May–June and September, while Frič and Vávra ('01) find it in the same stream near Podiebrad. They state that *B. cornuta* is found in great numbers in 1 m.–surface in summer months, and *B. longirostris* sparingly in the littoral fauna. Steuer ('01) finds *B.* "*longirostris-*

*cornuta*" in the backwaters of the Danube at Vienna in April–January. It exhibits a distinct seasonal polymorphism, with a *large* winter form and a *smaller* summer one. Data as to relative numbers during the year are not given. Skorikow ('02), in reviewing the investigations on the plankton of Russian waters, reports *B. cornuta* from the summer plankton of several streams, but expresses doubts as to whether "sie als autopotamische Planktonorganismen anzusehen sind oder nicht." Meissner ('03) finds *B. cornuta* generally in the Volga and its adjacent waters in the summer plankton, with largest numbers in August; and Zykoff ('03) reports it in small numbers from the same stream in May–July. It is not listed by Volk ('03) in the Elbe at Hamburg.

*B. longirostris* occurs generally in American waters, though apparently, often in small numbers. Thus Forbes ('82 and '90) reports it in the plankton of Lake Michigan and Lake Superior, and it appears generally in lists of *Cladocera* from many widely separated smaller bodies of water in this country. Birge ('95 and '97) finds only a few *Bosmina* (species not stated) in Lake Mendota, but Marsh ('97) reports it (species not given) as perennial in Green Lake, with a maximum in November. His records have also a suggestion of an earlier pulse, in June, in which month there is a sudden rise from a previous minimum.

This partial survey of the literature of the records of *Bosmina* in the plankton shows its wide distribution, suggests the probability of great variation, necessitating caution in the description of new species in this genus, and indicates a wide diversity in its seasonal career even in waters with somewhat closely similar environmental conditions.

*Ceriodaphnia megops* Sars was found singly but once—July 25, 1896, at 80°.

*Ceriodaphnia reticulata* Jurine was found in the plankton occasionally, and always in small numbers, in April–September. All occurrences appear at temperatures above 66°, and the earliest is on April 17, and the latest is September 21. Females with summer eggs were found in June–September.

*Ceriodaphnia rotunda* Straus was recorded in 1894–1895, but not thereafter. Its identification is somewhat questionable, and if correct, this is apparently the first record of this species in North American waters, unless it should appear that *C. alabamensis*

Herrick or *C. acanthinus* Ross, which appear to resemble *C. rotunda* in some particulars, should be included here as forms or synonyms. The genus is sadly in need of revision.

The forms referred to *C. rotunda* were found in August, 1894, and July–August, 1895, 16,536 per m.$^3$ appearing in the plankton on July 18 of the latter year.

*Ceriodaphnia scitula* Herrick.—Average number, 1,539. This species is closely related to the European *C. quadrangula* O. F. Müll., if, indeed, it is not identical with it. It is not impossible that it is the form imperfectly described by Say ('18) as *Daphnia angulata*. In the absence of a critical monograph of the genus I use the name applied in current American literature to this form.

This is the most abundant species of the genus in our waters, outnumbering all others by over sixfold in the totals of our records. It is also one of the most important members of the *Entomostraca* in the channel plankton (total of all records, 156,119), being exceeded in *numbers* only by *Moina micrura* (1,121,808), *Bosmina longirostris* (381,598), *Daphnia cucullata* (237,444), and *D. hyalina* (231,746).

It occurs in all months of the year except January and February, but in larger numbers and in more of the collections in May–September. Thus less than 6 per cent. (reduced to 2 per cent. if one collection in the warm autumn of 1897 is omitted) of the individuals and only 20 of the 79 occurrences are found outside of the May–September period. *Ceriodaphnia scitula* is accordingly a summer planktont in channel waters. It is found in each year, though in varying numbers according to hydrographic and other conditions. Thus in 1898 the vernal pulse in June attains the unsurpassed amplitude of 55,800 per m.$^3$, but declines in a fortnight and makes no recovery during the disturbed hydrographic conditions of the summer. In 1897, on the other hand, our records were too meager to delineate fully the vernal pulse, and in the stable conditions of the summer and autumn the species continued in numbers whose totals exceed those of 1898 by 81-fold. Similarly in 1896 the more gradual changes in levels which attended the floods of that year permitted a considerable development of *Ceriodaphnia* throughout the summer. Stable hydrographic conditions thus conduce to increase in *Ceriodaphnia*. The relations which I have shown to exist between *Bosmina* and movement in river levels (see table on page 228) exist also in the case of *Ceriodaphnia* and in much the same form.

The relation of temperature to *Ceriodaphnia* is evident in its seasonal distribution. It does not advance rapidly in its vernal increase until after the water warms to 70°, and drops suddenly in numbers when the autumnal decline passes this point. Moreover, seasonal variations in temperature are accompanied by corresponding shiftings of the pulses of *Ceriodaphnia.* Thus in 1898 the water did not reach 70° until about May 20, reaching 73° on May 24, and the vernal pulse of *Ceriodaphnia* began at once its rise to the maximum of June 7. In 1896 spring was early, 72° being recorded in surface waters on April 24, and we find a vernal pulse rising to a maximum on May 8. So also in 1897, when high temperatures continued into the autumn, the decline passing 71° on October 5, instead of in the first half of September as in other years, we find the pulses of *Ceriodaphnia* extending into October with unusual amplitude, reaching 5,200 per $m.^3$ October 5, while the highest record in this month, or later, in other years was 280 per $m.^3$ Temperature rather than season is thus the dominant factor in the seasonal curve of occurrence of *Ceriodaphnia.*

The form of this seasonal curve is typically that of a series of recurrent pulses of varying magnitude tending to reach the maximum height in the vernal pulse of May–June, attaining often lower levels in July and rising again in August–September, and falling to a minimum, or even to disappearance, in October. These later pulses do not appear in the disturbed hydrographic conditions of 1898 (Table I.), but are clearly delineated in the summer records of other years, especially in the stable conditions of 1897, where well-defined pulses appear in July, August, September, and October, at intervals of approximately four weeks, culminating July 14, August 10, September 14, and October 5. Their maxima attain respectively 5,600, 2,720, 6,000, and 5,200 per $m.^3$, and the pulses are delimited in each case by minima of less than 500 per $m.^3$ They tend to coincide with those of other *Entomostraca* and to approach those of the *Rotifera.*

The *Ceriodaphnia* population in channel waters is almost exclusively made up of parthenogenetic females. Males were not recorded at any time, though females with ephippial eggs appeared after the October pulse of 1897 and the vernal one of 1898.

*Ceriodaphnia scitula* appears but once in the records of European plankton, Scourfield ('98) finding it in the waters of Epping Forest in September. The closely related *C. quadrangula* as well as the other species have been frequently recorded by European investigators both in the littoral and the limnetic fauna, but they appear to be less generally found there than the other dominant *Cladocera* of our waters.

It does not appear in the plankton of our Great Lakes (Forbes '82 and '90, Birge '95), or in that of Lake Mendota (Birge '95 and '97), or Green Lake (Marsh '97), but Herrick ('84) reports it as the most abundant species in Minnesota, and Fordyce ('00) finds it in Nebraska in shallow waters. A revision of the genus is needed before the seasonal distribution of the various species can be worked out on a basis that will make satisfactory discussions of the literature possible.

*Chydorus sphæricus* O. F. Müll.—Average number, 422, of which 26 are egg-bearing females, and 6 are immature, the remainder, 390, being females in which the ova were not prominent.

The identification of species of *Chydorus* is attended by considerable uncertainty. Comparison with named specimens from Europe supplied by Prof. G. O. Sars, leaves no doubt that *C. sphæricus* is common in our waters, and it is apparently the dominant species. It is probable that several other species, as, for example, *C. globosus* Baird and *C. cælatus* Schoedler, occur sparingly in our waters and have been included with *C. sphæricus* in my enumerations. The difficulties which attend the attempt to assign *every* individual to one of the several species of *Chydorus* can be appreciated only by one who makes the effort. The problem of their specific validity should be solved by a statistical analysis of the range of variation.

The seasonal distribution of *Chydorus sphæricus* in channel waters is in its general outlines very characteristic and well defined. The following table, which gives the average number of *Chydorus* per $m.^3$ for each month of our collections, shows clearly that it is a vernal planktont, and that there is a slight tendency toward an autumnal pulse in September, when vernal temperatures return. The number for November (222) would probably be considerably reduced if more than one collection had been taken in that month in 1896. Omitting this year, the average for November falls to

78, and a secondary, hiemal rise becomes apparent in December. This December pulse of *Chydorus* is one of the elements in the upward movement of production in this month (see Part I.), and fuller data may serve to connect it fully with the September–October pulse, especially in more stable conditions. Both of these autumnal-hiemal movements have less than one tenth of the development that the vernal pulse exhibits.

The number and percentage of occurrences also confirm the conclusions drawn from the numbers per m.[3] Percentages run higher in the spring, in March–May, and in September–October and in December, and lower in June–August, November, and January–February. *Chydorus* occurred in all March collections, and in only one third of the August collections.

The analysis of the data in this table indicates the presence of *Chydorus* in the plankton practically throughout the whole year in the whole seasonal range in temperatures, with the larger developments following shortly after the thermograph passes the yearly mean (57° average of monthly means of surface waters) in vernal rise and autumnal decline, the maximum development in April–May

SEASONAL DISTRIBUTION OF CHYDORUS. AVERAGE NUMBER PER M.[3]

| Year | Jan. | Feb. | March | April | May | June |
|---|---|---|---|---|---|---|
| 1894 | —— | —— | —— | —— | —— | 234 |
| 1895 | —— | 11 | —— | 2,044 | —— | 0 |
| 1896 | 304 | 167 | 1,682 | 10,271 | 5,701 | 448 |
| 1897 | —— | 20 | 540 | 320 | 32,800 | 900 |
| 1898 | 160 | 0 | 256 | 300 | 3,364 | 356 |
| 1899 | 36 | 65 | 193 | —— | —— | —— |
| Average | 167 | 53 | 668 | 3,235 | 13,955 | 388 |
| No. of occurrences | 9 | 6 | 15 | 9 | 9 | 10 |
| Percentage of occurrences | 75 | 40 | 100 | 82 | 90 | 72 |

SEASONAL DISTRIBUTION OF CHYDORUS. AVERAGE NUMBER PER M.³—*continued.*

| Year | July | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|
| 1894 | 95 | 0 | 461 | 100 | 16 | 56 |
| 1895 | 91 | 103 | 164 | 38 | 203 | 448 |
| 1896 | 64 | 104 | 78 | 160 | 800 | 277 |
| 1897 | 213 | 40 | 407 | 650 | 64 | 115 |
| 1898 | 50 | 0 | 30 | 60 | 28 | 172 |
| 1899 | —— | —— | —— | —— | —— | —— |
| Average | 103 | 49 | 228 | 202 | 222 | 214 |
| No. of occurrences | 11 | 7 | 13 | 12 | 10 | 14 |
| Percentage of occurrences | 61 | 33 | 81 | 71 | 63 | 82 |

occurring in average temperatures, for these months, of 60.5° and 68.3°, while the minor autumnal development appears in September–October at 74.2° and 57.6° respectively, and the December pulse, if indeed it be a separate and independent pulse, is at the low temperature of 35.2°. The December movement may be simply the result of the more stable conditions which attend the appearance of the ice-sheet on the approach of winter.

An analysis of the course of the seasonal distribution of *Chydorus* in channel waters, as given in Table I. and in statistics of other years, indicates the following seasonal regimen. In January–February, at minimum temperatures, the occurrences are irregular (75 and 40 per cent.) and the numbers small (average, 167 and 53 per m.³), while in March, with rising temperatures, occurrences are more numerous (100 per cent.) and numbers rise to 668 per m.³ In April–May a high percentage of occurrences (82 and 90 per cent.) continues, and they mount rapidly to the maximum record of the year, which in our statistics varies from 4,088 in 1895 to 32,800 in 1897. This vernal pulse reaches its maximum in our records on April 29 in 1895, at 64°, and in 1896 on the same day, at 70°; on

May 25 in 1897, at 66.3°; and on May 24, in 1895, at 73°. From this maximum the pulse declines abruptly in a fortnight to a midsummer minimum during maximum temperatures, which continues until September. During this period the numbers are small, rarely rising above 400 per m.³ (average, 388, 103, and 49), and the occurrences are also less numerous (72, 61, and 33 per cent.). With the decline of temperatures which begins in September the percentage of occurrences mounts to 81, and the average per m.³ to 228, and remains near this level during the remainder of the year.

An analysis of the full statistical data, of which the records for 1898 are fairly typical, confirms the conclusions drawn from these averages. *Chydorus* in channel waters is monocyclic, with a well-defined vernal pulse in March–June which includes 95 per cent. of the total annual *Chydorus* population. There are suggestions of an autumnal pulse, but the data are not sufficient to delimit it. There is no satisfactory evidence that there are recurrent cycles or pulses at briefer intervals during the year.

The dominating effect of temperature as a regulating factor in delimiting the seasonal distribution of *Chydorus* is very evident. This, in addition to its appearance in the annual curve of occurrences, is also exhibited most clearly in a comparison of the vernal pulses in the two years of fullest representation in our records, 1896 and 1898. The following table gives the data of dates, temperatures of surface waters, and numbers of *Chydorus*.

From these facts it appears that the late spring of 1898 delayed the vernal pulse of *Chydorus*, and that the early spring of 1896 accelerated it in that year so that their apices (April 29 and May 24) are four weeks removed from each other in seasonal location. In both years the rapid rise in the pulse *appears after 60° is passed, the culmination occurs at about 70°*, and the decline, *in temperatures above 70°*.

Egg-bearing females were more abundant during the rise of the pulse, and less numerous during its decline. Evidence of great mortality during the decline of the pulses is to be found in great increase in the relative numbers of empty carapaces. Thus, during the decline of the vernal pulse in 1896 there were on the day of culmination, April 29, 2,780 dead to 18,904 living, on May 1, 3,570 to 14,875, and on May 8, 1,578 to 6,706. From 14 to 24 per cent. of the *Chydorus* population had thus recently perished. Parasitized

| 1896 | | | 1898 | | |
|---|---|---|---|---|---|
| Date | Temperature | No. of *Chydorus* | Date | Temperature | No. of *Chydorus* |
| Mar. 17..... | 42° | 256 | Mar. 15.... | 46° | 440 |
| " 24...... | 40.7° | 610 | " 22.. . | 51° | 480 |
| " 30...... | 48.1° | 6,405 | " 29.... | 49.5° | 240 |
| Apr. 10...... | 46.4° | 1,666 | Apr. 5.... | 48.3° | 200 |
| " 17...... | 66.3° | 4,515 | " 12.... | 52° | 200 |
| " 24...... | 72° | 15,900 | " 19.... | 56° | ——— |
| " 29...... | 68° | 18,904 | " 26.... | 57° | 800 |
| May 1...... | 68.8° | 14,875 | May 3..... | 60° | ——— |
| " 8...... | 76° | 6,706 | " 10..... | 62° | 600 |
| " 18...... | 71.2° | 1,143 | " 17..... | 64° | 3,300 |
| " 25...... | 75.3° | 80 | " 24..... | 73° | 7,880 |
| | | | " 31..... | 70° | 5,040 |
| June 6..... | 79° | 320 | June 7.... | 78° | 600 |
| " 11..... | 73° | 320 | " 14.... | 82.3° | 200 |

and fungused individuals were also noted in these periods of decline. Males were recorded in September, December, and February.

*Chydorus* is not given as a constituent of the plankton of Norwegian lakes by Huitfeldt-Kaas ('98) or of Swiss lakes by Fuhrmann ('00), Amberg ('00), or Burckhardt ('00 and '00a). Its absence from these cooler waters stands in sharp contrast with its abundance in warm and shallow European lakes. It is reported as abundant in *Chroococcaceæ*-rich lakes of North Germany by Apstein ('96), where it is acyclic, with larger development in April–October, and maximum in August or in May–June. According to Weismann ('79) *Chydorus* in some waters is polycyclic. It is also reported by Zacharias ('97a and '98b) from the pond fauna of Trachenberg and many other German localities, where it forms "ein notorisches

Mitglied des Teichplanktons." He also lists it ('98b) from some German streams. Marsson ('00) found it in some waters near Berlin in April–August, noting a great abundance in one instance in May. Seligo ('00) gives a few statistical data indicating the occurrence of *Chydorus* in the plankton of Hintersee near Danzig in April–December, with a maximum in August and a secondary one in October. It was, however, sparingly present in adjacent waters. Cohn ('03) finds a like irregularity in its occurrence in waters near Königsberg.

Stenroos ('97) finds it to be one of the most abundant *Entomostraca* in the waters of northern Russia and ('98) a littoral and bottom species near Helsingfors. Scourfield ('98) finds it to be one of the most abundant *Cladocera* in the waters of Epping Forest, occurring from March to December, with maxima of sexual reproduction in April and November. Scott ('99) reports it as abundant in the littoral fauna of Scottish waters, but rare in tow-net collections in open water.

It also occurs in the potamoplankton of European streams, Zacharias ('98b) listing it from a few minor streams, but without seasonal, statistical, or temperature data. It was not separately listed by Skorikow ('97) in the summer plankton of the Udy at Charkow, or by Lauterborn ('94) in the winter plankton of the Rhine. Zimmer ('99) found it from February to July in the Oder, and Schorler ('00) finds it abundant in the plankton of the Elbe in April. Steuer ('01) finds it at all seasons in the backwaters of the Danube at Vienna, and in the plankton from March to November "oft in grössern Mengen," but gives no statistics of its seasonal distribution. Frič and Vávra ('01) find it in the channel and backwaters of the Elbe near Podiebrad, but more abundant in the littoral fauna, though no quantitative or statistical data of its occurrence are given. Zykoff ('03) reports it as present in the plankton of the Volga at all times in small numbers, and suggests a predominance in May–July. Meissner ('03) also reports it for the Volga, but states that it is predominantly a member of the littoral fauna though present in the plankton of the stream in restricted numbers. No statistical data are given by him. Volk ('03) reports it in the Elbe at Hamburg, but without any details.

This species is reported generally from American waters. Forbes ('90) reports it in the summer plankton of Lakes Superior and

Michigamme in small numbers, and ('93) in that of the Alpine waters of Wyoming and Montana, where it is, however, more abundant in smaller pools. Birge ('94) finds it generally distributed in collections, including plankton, in Lake St. Clair and ('97) a member of the plankton of Lake Mendota, where its abundance is dependent on the supply of *Anabæna*. Its maximum—only a single well-defined one occurring in each year—was found in July–October. Birge regards it as an accidental member of the limnetic fauna, maintained there as long as suitable food is present. Its mode of occurrence does not, however, differ from that of typical plankton organisms, which would doubtless likewise disappear from the plankton if their food should be lacking.

It is noteworthy in this connection that it was only sparingly present in the channel of the Illinois in the midsummer–autumn plankton, when—as, for example, in 1897—*Anabæna* and its allies were abundant. It seems not improbable that temperature even more than food is an important factor in controlling its seasonal and local distribution. It is unquestionably a member of the *plankton* in our waters, though also abundant here, as elsewhere, in the littoral fauna. In our locality in channel plankton it shows distinctly seasonal limitations which suggest the operation of temperature rather than food. Its occurrence in large numbers in Wisconsin lakes in midsummer and its absence in the Illinois at that time may also be correlated in part with the contrasted temperature conditions in the two localities. Its occurrence in our littoral fauna may also in part be due to the lower temperatures consequent upon spring-fed areas and the shade of aquatic vegetation. *Chydorus* is one of those organisms capable of *both the littoral and limnetic habit* under suitable conditions of food and temperature. In our waters, at least,—and, as it seems from the data of distribution, elsewhere,—temperature, rather than food directly, appears to be the factor controlling the occurrence of *Chydorus* in the plankton.

*Daphnia cucullata* G. O. Sars.—Average number, 181. In 1897, very much greater,—5,483 per m.$^3$

For the reasons given by Burckhardt ('00) I use Sars's name *cucullata* rather than *jardinei* of Richard to designate those forms of the subgenus *Hyalodaphnia* in our plankton. In channel waters this species varies considerably, but not to the extent that it does where its numbers are greater. The forms known as *apicata* Kurz and *kahlbergiensis* Schoed. appear in small numbers in some years.

This species appears in our collections in April–December only, with the exception of one occurrence in January and two in March. Its occurrences and numbers vary greatly in different years. In 1894–95 its numbers were small and occurrences scattering, it being most abundant in November–December. In 1896 there was a large vernal development in April–June, and a series of diminishing pulses in July–September. In 1897 no vernal development appeared in our scattered collections, but in the stable conditions of late summer and autumn occurred the largest development recorded in any year, with a maximum record of 72,760 per m.³ on October 5. In 1898 there was a small vernal development (3,400) in May–June and a still smaller one (600) in October. A well-defined seasonal routine is thus not demonstrable from our data, though the fact that both the percentage of occurrences and the numbers are highest in May–June and September–October suggests a tendency toward vernal and autumnal pulses separated by a period of less development in midsummer and of autumnal decline followed by a period of almost complete extinction in midwinter.

The statistics of the *D. cucullata* population in all years in which weekly collections were made, exhibit very clearly the phenomenon of recurrent pulses of 3 to 5 weeks' duration, with maxima of varying amplitude and minima of less than 400 per m.³ in all cases but those which mark the September pulse of 1897. There are in 1896 pulses culminating April 24 (2,544 per m.³), May 8 (11,965), June 11 (12,000), July 18 (1,040), August 8 (800), and September 16 (507). In 1897, vernal records are incomplete. Pulses appear July 14 (800), August 17 (1,680), September 14 (57,000), October 5 (72,760), and November 15 (2,040). These pulses coincide exactly or approximately with those of the other *Entomostraca* which exhibit the same phenomenon, and approximate also those of the *Rotifera*. A typical pulse, that of October, 1897, is shown in the following table. It is a noticeable fact that the *proportion* of immature forms is often greater at and after the period of maximum development than at other times, as appears in the table.

The relations of temperature to the development of *D. cucullata* in channel waters appear in the fact that all occurrences in excess of

| Date | Females | Females with eggs | Young | Total | Percentage of young |
|---|---|---|---|---|---|
| Sept. 27 | 160 | 320 | 640 | 1,120 | 57 |
| " 29 | 7,520 | 4,000 | 12,800 | 24,320 | 52 |
| Oct. 5 | 3,560 | 10,800 | 58,400 | 72,760 | 82 |
| " 12 | 1,600 | ——— | 7,600 | 9,200 | 83 |
| " 19 | 560 | 840 | 4,440 | 5,840 | 76 |

600 per m.$^3$ are found after the temperatures pass 70°, with the single exception of the decline of the October pulse and the rise of the November pulse to 2,040 per m.$^3$ at 47°, following the high temperatures in the late autumn and stable conditions of 1897. From the depression in numbers during the period of maximum heat in midsummer and the occurrence of the major vernal and autumnal pulses before and after its reign it appears that the temperature optimum for *D. cucullata* in channel waters lies below this level, that is, below 80°.

*D. cucullata* is evidently very easily affected by the changes in hydrographic conditions. Thus, in July–December, 1897 and 1898, the total movement in river levels was 12.4 and 31.4 ft., respectively, while the total *cucullata* population for these months was 186,420 and 1,140—164-fold greater in the more stable year. *D. cucullata* thus exhibits the maximum sensitiveness among the *Entomostraca* to these environmental factors.

The *D. cucullata* population in the plankton consists almost entirely of parthenogenetic females and young. The immature stages form about 60 per cent. and the egg-bearing females 16 per cent. of the total individuals. Dead, parasitized, or fungused individuals were found at times of the maxima or shortly thereafter, but never in very large numbers. Males were found once in December, 1896, and ephippial females also but once, on October 19, 1897, during the decline of the maximum pulse in our records.

*Daphnia cucullata* var. *apicata* Kurz, in well-developed condition, was found in relatively small numbers during the vernal pulses of 1895 and 1896 and the autumnal pulse of the former year.

Incipient stages of this variety appeared also at other times. Burckhardt ('00a) does not even concede varietal standing to *apicata*, regarding it merely as a form of seasonal or local value. Its occurrence in our plankton when reproduction and growth are most active suggests that it may have a growth value, and be in some way correlated with the factors involved in its cyclic production.

*Daphnia cucullata* var. *kahlbergiensis* Schoed. appears but once in our records—in the plankton of June 11, 1896.

The *D. cucullata* group is a cosmopolitan constituent of the fresh-water plankton, appearing frequently in the records of European plankton. Apstein ('96) finds it in lakes in northern Germany in April–October with maximum numbers in July. The seasonal limits thus resemble those in the Illinois, but the maximum falls at the time of our midsummer decline. Temperatures in these German lakes (16.3° C.) do not, however, reach the high levels attained in our waters in midsummer. Stenroos ('98) records it in several varieties in the plankton of Nurmijärvi See, the helmeted varieties being found in midsummer. Zacharias records it from the plankton of German ponds. Scourfield ('98) finds it in small numbers in Epping Forest interruptedly in April–November, a season coinciding with that in the Illinois. Burckhardt ('00) finds it represented by five different "forms" in Mauensee in the June plankton. Marsson ('00) finds representatives of *Hyalodaphnia* (species not given) in the April–June plankton near Berlin. Amberg ('00) states that this species appears in April, increasing to a maximum in July–August, and disappears again at the end of November, a seasonal course similar in limits but not in maximum to that in the Illinois. His data are too scattered to trace the course of production with completeness. Seligo ('00), in waters near Danzig, finds the species present in June–January, with maxima in June–July and October. In the period of maximum summer temperatures (16°–21° C.) the numbers decline as in this period in the Illinois. In Seligo's infrequent (two to three weeks' interval) data there are suggestions of minor recurrent pulses in other months. Cohn ('03) finds in Löwentin a *Daphnia* which he calls *D. galeata* with vars. *kahlbergiensis* and *cederströmii*, and includes all three in his enumeration. His investigation covers the months of May–September, throughout which these forms appear, rising in a series of recurrent maxima on June 26, August 4, and September 2 and 29.

Cohn seems not to have called attention to these clearly defined recurrent pulses.

In European streams *D. cucullata* also forms an important part of the plankton. Lauterborn ('93) states that, with its varieties *kahlbergiensis* and *cederströmii*, it appears abundantly in the plankton of the Rhine in summer, but is not found in it in winter. Zimmer ('99) states that *D. kahlbergiensis* was found constantly in the plankton of the Oder in July–September, and Schorler ('00) also finds it in the Elbe at Dresden in May–August, with larger numbers in June and August. Steuer ('01) reports it, in small numbers only, in August in the backwaters of the Danube at Vienna. Frič and Vávra ('01) report *D. kahlbergiensis* as rare in the Elbe. Sowinski ('88) finds it in several varieties in plankton of the Dnieper and its tributaries, Rossinski ('92) finds it in the summer plankton of the Moskwa, and Zernow ('01) in the June–July plankton of the Schoschma and Wjätka. Meissner ('02 and '03) finds it in several varieties in the May–August plankton of the Volga.

*D. cucullata* in some of its various forms or varieties appears to be widely distributed in American waters. It was reported by Forbes ('82), as *D. retrocurva*, from the plankton of Lake Michigan, and also ('90) from Lake Superior and adjacent waters. Birge ('91 and '94) also finds it abundantly in Wisconsin waters and in Lake St. Clair. Herrick ('84) and Ross ('97) report it from Minnesota and Iowa. Careful studies of its seasonal and vertical distribution in Wisconsin waters have been made by Marsh ('97) in Green Lake, and by Birge (95 and '97) in Lake Mendota. In Green Lake *D. kahlbergiensis* is reduced to a minimum or even extinction in December–April, rises in a late vernal maximum in June–July, falls again to a lower level in August–September, and then rises to a second and sometimes higher autumnal pulse in October. In its main outlines this conforms to the seasonal course of the *cucullata* form in our channel plankton. Our vernal maximum appears somewhat earlier, as a result probably of an earlier warming up of the water. According to Birge ('97) this species is more definitely periodic in its occurrence in Lake Mendota, being confined entirely to July–December. Here also the largest numbers are found in October, and the individuals gather in lower levels as temperatures decline.

*Daphnia hyalina* Leydig.—Average number, 417. In channel waters this species has appeared in but two years, in 1895 in April–July, attaining on June 19 a maximum of 166,208 per m.³, of which 150,626 were immature. The collections were too infrequent in these months to trace the course of this vernal pulse. *D. hyalina* did not reappear until the spring of 1898, on May 24, in a single vernal pulse culminating at 11,600 per m.³ on June 7, and disappearing a fortnight later. Its occurrences with one exception were all at temperatures above 70°. There is no apparent cause for its absence in later months or in other years. Males and ephippial eggs were not found.

*Daphnia hyalina* is an exceedingly variable species, and a large number of forms have been described which belong to the *hyalina* group. Burckhardt ('00), for example, recognizes 26 such forms as varieties of this cosmopolitan planktont. This variability and the difficulties attending the resulting synonymy cause any discussion of the species in other waters to be attended by much uncertainty. I shall therefore not attempt to distinguish in my discussion between the various varieties included by Burckhardt in the *hyalina* group.

In lakes of northern Germany, Apstein ('96) finds that *D. hyalina* is essentially a winter planktont with a seasonal range of September–July, and with maximum numbers in November–January. The maximum thus appears there at the time of complete extinction in our waters. Stenroos ('97) records it (as *D. galeata*) in the summer plankton of Karelia, Huitfeldt-Kaas ('98) finds it in Norwegian lakes in July and September in considerable numbers, and Scourfield's careful studies ('98) of its seasonal occurrence in waters of Epping Forest reveal an interrupted distribution in April–November. Scott ('99) finds it in numbers in Scottish lochs in the plankton examined at long intervals in March–January. Fuhrmann ('00) reports it as perennial in Neuenbergersee, with a maximum in June followed by a midsummer minimum. Burckhardt ('00a) finds great diversity in different Swiss lakes and in different years in the relative numbers present. His intervals of collection were too great to detect any pulse-like movement in the production, and it may be that the diversity is due in part to the incompleteness of his records. He concludes that *D. hyalina* is at a minimum in March–May, increases in numbers slowly (with a preponderance of young individuals) in May–October to a maximum in November–January, which is followed by a rapid decline (with preponderance of adults) to the minimum. His results agree with those of Apstein ('96) in the main rather than with ours in the Illinois. Seligo ('00) finds *D. hyalina* in Hintersee, though it is apparently absent from the adjacent Barlewitzersee. In the former lake it appears in May, rising to the year's maximum early in June, continuing throughout the summer in diminished numbers, and disappearing in October. In his infrequent records there are suggestions of several recurrent minor pulses during the summer. Cohn ('03) reports *D. galeata*—regarded by Burckhardt ('00a) as a form of *D. hyalina*—from the region of Königsberg, but refers it rather to the *cucullata* group. I shall therefore consider his results only in connection with *D. cucullata*.

*D. hyalina* appears but rarely in the records of European potamoplankton. Steuer ('01) reports it, in small numbers only, in May from the backwaters of the Danube at Vienna. Frič and Vávra ('01) state that *D. microcephala*—regarded by Burckhardt ('00a) as a form of *D. hyalina*—is abundant in the plankton at a depth of 0–1 m. in April–November in the Elbe and its backwaters at Podiebrad. It is also reported by Zykoff ('00 and '03) in the late vernal (June–July) plankton of the Volga at Saratoff, and by Meissner ('02 and '03) in the same stream in May–June. The examination of the plankton of the Volga made by these authors is far less extensive than that made of the Illinois River plankton, but as far as it goes it indicates a similar distribution of *D. hyalina* in the two streams. Volk ('03) reports it from the Elbe at Hamburg without data.

The species appears to be widely distributed in American waters, being reported, in some of its various varieties or synonyms, especially from lakes and ponds. Smith ('74) finds it in the plankton of Lake Superior, Forbes ('82) in that of Lake Michigan, and Birge ('94) in Lake St. Clair. It was also found in the Illinois by Forbes ('78) and in the backwaters of the Ohio River by Herrick ('84), who reports it also from Minnesota waters. Birge ('91) finds it in lakes about Madison, Wis., and Fordyce ('00) in deep pools in western Nebraska. The only investigation of its seasonal distribution in American waters is that of Birge ('95 and '97) in Lake Mendota, where it forms about 3 per cent. of all the *Crustacea*. It is perennial in this lake but exhibits great differences in its seasonal course from year to year. The vernal development in May–June (the only one in our channel plankton) is relatively large in each year, but is sometimes exceeded by an autumnal one in October. A midsummer minimum sometimes appears between these pulses, and a winter minimum in December–April is always present.

From the data here reviewed it seems probable that the very limited seasonal distribution and irregular annual recurrence of *D. hyalina* in our channel plankton is in a measure indicated in streams elsewhere, and may have its cause in the instability of the fluviatile environment as compared with the lacustrine, where the species evidently finds its environmental optimum.

*Diaphanosoma brachyurum* (Liévin).—Average number, 479, of which 154 are females, 49 females with eggs, and 276 immature.

This species in our waters is monocyclic, with sharply defined seasonal distribution. With the exception of two records of young individuals in March–April, 1895 (and the identification of these individuals is questionable), all our records of occurrence in 1894–1899 fall between May 25 and October 19, the first vernal records appearing at temperatures of 55.8° to 72.3°, and the last autumnal at 52.5° to 65°. The one pulse in each year—except in 1894, when none was recorded—falls in a period of 3–6 weeks in July–September, the first record above 2,000 per $m.^3$ appearing July 26, and the latest (with one exception, 2,175 on September 27, 1895) on September 7. The pulse varies in duration in different years from 3 to 6 weeks, and attains a maximum on dates ranging from July 26 to August 31, and varying in amplitude from 8,580 to 19,602 per $m.^3$ An analysis of the distribution of 61 recorded occurrences in channel plankton shows that of these only 13, or 21 per cent., occur outside of July–September, and that the records outside of the seven weeks of the pulse include less than 12 per cent. of the total individuals.

A comparison of the seasonal curve of distribution with the annual thermograph reveals the fact that the pulse occurs toward the close of the period of maximum summer heat, and in every case at a temperature of 78° or above, and that the decline of the pulse often begins with declining temperatures, and is always accomplished during the autumnal decline. The effect of summer heat pulses upon the *Diaphanosoma* curve is strongly suggested by the data of the appended table, which gives the statistics of temperature, river level, and *Diaphanosoma* population during the periods of maximum development in 1895–1898. All these data except those of *Diaphanosoma* are shown graphically in Part I., Plates IX.–XII. The data for *Diaphanosoma* are less complete than the others, since all of the collections were not counted.

In 1895 the *Diaphanosoma* pulse culminates at 19,602 on August 21, following immediately upon a heat pulse which culminates August 15 at 85.3°. The decline of the pulse occurs with a decline of temperature to 72° on September 7. The declines, both of *Diaphanosoma* and temperature, are hastened after September 3 by

| 1895 | | | | 1896 | | | |
|---|---|---|---|---|---|---|---|
| Date | River gage | Temp. | No. of *Diaphanosoma* | Date | River gage | Temp. | No. of *Diaphanosoma* |
| —— | —— | —— | —— | July 2 | 5.15 | 80.8 | 40 |
| —— | —— | —— | —— | " 10 | 4.00 | 79.5 | 800 |
| —— | —— | —— | —— | " 18 | 2.50 | 79 | 400 |
| July 23 | 5.20 | 80 | 424 | " 23 | 4.20 | 80 | 120 |
| " 29 | 5.38 | 75.5 | 240 | " 28 | 6.40 | 82 | 7,440 |
| Aug. 1 | 4.20 | 78.5 | 1,088 | Aug. 3 | 8.50 | 80.3 | 160 |
| " 8 | 2.63 | 79 | 988 | " 8 | 8.40 | 86 | 14,260 |
| " 12 | 2.40 | 84.8 | 9,801 | " 15 | 7.40 | 82 | 2,240 |
| " 21 | 2.08 | 81.5 | 19,662 | " 21 | 7.10 | 79 | 880 |
| " 29 | 2.58 | 80 | 7,950 | " 26 | 6.50 | 77.5 | 600 |
| —— | —— | —— | —— | " 29 | 6.00 | 74.3 | 440 |
| Sept. 5 | 5.70 | 74 | 189 | Sept. 16 | 4.10 | 73.5 | 663 |
| " 12 | 3.90 | 79 | 1,053 | " 30 | 4.30 | 58 | 80 |
| " 20 | 3.20 | 79 | 468 | —— | —— | —— | —— |
| " 27 | 3.23 | 73 | 2,175 | —— | —— | —— | —— |

| 1897 | | | | 1898 | | | |
|---|---|---|---|---|---|---|---|
| Date | River gage | Temp. | No. of *Diaphanosoma* | Date | River gage | Temp. | No. of *Diaphanosoma* |
| July 14 | 6.30 | 79 | 160 | July 12 | 7.00 | 78 | 60 |
| " 21 | 5.20 | 81.1 | 960 | " 19 | 4.70 | 84 | 40 |
| " 30 | 4.60 | 84 | 4,720 | " 26 | 2.90 | 89 | 8,580 |
| Aug. 10 | 2.30 | 80.8 | 7,600 | Aug. 2 | 2.70 | 78.3 | 6,960 |
| " 17 | 1.90 | 79 | 7,120 | " 9 | 3.20 | 83 | 360 |
| " 24 | 1.80 | 77.5 | 5,120 | " 16 | 3.70 | 77 | 60 |
| " 31 | 1.80 | 80 | 11,000 | " 23 | 4.20 | 82 | 1,020 |
| ——— | —— | —— | ——— | " 30 | 3.90 | 82.5 | 2,520 |
| Sept. 7 | 1.80 | 80 | 7,600 | Sept. 6 | 4.70 | 79 | 240 |
| " 14 | 2.00 | 83 | 1,500 | " 13 | 4.20 | 62.5 | 1,800 |
| " 21 | 2.00 | 71 | 240 | " 20 | 4.20 | 73 | 960 |
| ——— | —— | —— | ——— | " 27 | 4.90 | 73 | 400 |

the rise in river levels. Prior to that date hydrographic changes are slight. With falling levels and higher temperatures after September 7 there is a slight recovery in *Diaphanosoma*—from 189 per m.$^3$ on the 5th, to 1,053 on the 12th.

In 1896 a well-defined heat pulse culminates August 10 at 86.5°; and *Diaphanosoma*, on August 8 at 14,260, with an abrupt depression from 7,440, on July 28, to 160, on August 3, in flood waters. The decline of this pulse from the maximum on the 8th to 440 on the 29th is attended by a uniform decline in temperatures from 86° to 74.3° in fairly stable hydrographic conditions, that is, declining river levels.

In 1897 there are two well-defined summer heat pulses, one culminating August 3 at 89°, and the other September 14 at 83°, separated by a depression to 77.5° on August 24. The crest of the *Diaphanosoma* pulse likewise has two apices, the first culminating at 7,600 on August 10, followed, during the decline in temperatures, by a fall to 5,120 on the 24th, and, in the rising temperatures which then ensue, by a recovery to a second maximum of 11,000 on the 31st. *Diaphanosoma* then declines though temperatures continue to rise. These fluctuations all take place in comparatively stable hydrographic conditions. There is a suggestion in the records of this year that rising temperatures in midsummer conditions tend to accelerate, and falling temperatures to depress, development of the *Diaphanosoma* pulse, and also that after the pulse has continued for some time (six weeks in this instance) rise in temperature ceases to be effective. The autumnal decline in *Diaphanosoma* may therefore not *always of necessity be due to temperature decline alone.*

In 1898 there are also two midsummer heat pulses, culminating on July 26 at 89°, and August 30 at 82.5°, separated by a depression which reaches 77° on August 16. The depression to 78.3° on August 2, with the consequent appearance of a third summit at 83° on August 9, is due mainly to the fact that the temperature was taken at 9:15 a. m., while all the others were in the late afternoon. The seasonal curve of *Diaphanosoma* shows likewise two apices, the first at 8,580 on July 26, and the second at 2,520 on August 30, separated by a depression to 60 per m.[3] on August 16, when temperatures are lowest. In this year the flood of the middle of August doubtless plays a large part in depressing alike the thermograph and the seasonal curve of *Diaphanosoma*, but in the light of the evidence from 1897 in stable hydrographic conditions the direct influence of temperature is also possible in this instance.

*Diaphanosoma* is thus a late summer planktont which in development is very responsive to changes in temperature. It appears in the plankton in small numbers shortly after the establishment of summer temperatures in May–June, but does not begin its maximum development until maximum summer temperatures have existed for six to eight weeks, and is apparently incited to this by a summer heat pulse.

Males were recorded on July 18 and August 1, and ephippial females on August 1 and September 5. Dead individuals were most numerous during or subsequent to the maximum of the pulse.

This species is reported by Apstein ('96) in the plankton of Dobersdorfersee, where it is also monocyclic, first appearing in May, and attaining its maximum in September, when the males first appear. In contrast with conditions in our waters the maxima appear *after* the period of maximum summer heat. Zacharias ('97a) reports it from German carp ponds in July, and Stenroos ('97) lists it as a *littoral* species in midsummer in northern Russia. Scott ('99) finds it rarely in lakes of Scotland in August, and then only in the plankton, though many shore collections were examined. Burckhardt ('00) reports it from the smaller and shallower Swiss lakes in isolated records ranging from May to November, and regards its absence from the deeper lakes as due to the low temperatures which at all seasons would surround its winter eggs, which sink to the lower levels. In Vierwaldstättersee ('00a) he finds this species in the plankton only in September–November, and then more abundantly near shore than in the middle of the lake. In Alpnachersee the period of occurrence extends from June to November with a maximum in July. Fuhrmann ('00) gives the seasonal distribution in Neuenburgersee as extending from May to November, with a maximum in September. Marsson ('00) finds a seasonal distribution from July to October in small lakes near Berlin. Seligo ('00) finds in Hintersee, near Danzig, a seasonal distribution in 1898 extending from June 6 to October 18, with a maximum of 225,000—under 1 sq. m., depth, 24 m. (?)—on August 9. Frič and Vávra ('01) state that this species is very abundant in summer months in the plankton of the backwaters of the Elbe, especially in levels at depths of 0–1 meter. Cohn ('03), on the other hand, finds in waters near Königsberg that *Diaphanosoma* is present in greatest abundance in depths of 20–30 meters. It occurs in summer months, with large numbers in July–September and a maximum in August–September. It was not found in shallow waters.

As a constituent of the potamoplankton *Diaphanosoma* has been reported by Schorler ('00) in the Elbe at Dresden as abundant in June–September. Steuer ('01) finds it in the backwaters of the Danube at Vienna in June–September, with a maximum in August, but never in great numbers. Meissner ('03) reports it sparingly from the Volga in July.

In American waters *Diaphanosoma* is widely distributed. Forbes ('90) found it abundant below surface levels in Lake Michigamme in August. Birge ('94) reports it in the plankton of western Lake Erie but not in that of Lake St. Clair in September. In Lake Mendota, Wis., he ('95 and '97) has worked out its seasonal and vertical distribution with a fulness and care not equaled by any

European author previously quoted. Our results in Illinois waters are in striking confirmation of his conclusions. He finds the first scattering individuals in the plankton late in May, but numbers do not rise until late in July or early in August, increasing rapidly through August or even into September, then declining rapidly, and disappearing entirely before November 1. The active period is thus at a time when a considerable part of the lake is at or above 68°. In our waters these temperature limits are 78° or above, but the seasonal distribution is almost identical with that in Lake Mendota. He finds it more abundant in the upper strata, 0–2 meters, than in the deeper ones—just the opposite of Cohn's ('03) results. Marsh ('97) has also determined its seasonal and vertical distribution in Green Lake, Wis., with considerable care. Occurrences from the last of October to the last of June are very few, and maximum numbers appear from the middle of August to the middle of September, when surface waters have a temperature of 65°–80°. It occurs in all depths (0–40 m.), but 70 to 80 per cent. of the individuals were taken within 10 to 15 m. of the surface, the upper 5 meters being more densely populated by night than by day and in September–October than in August.

*Diaphanosoma* is a typical planktont, with strong antennæ, and an active swimmer. Examination of the literature indicates its wide distribution in the plankton of lakes and streams, and its very marked seasonal limitation to seasons of higher temperature. It is thus, as Birge ('97) has stated, markedly stenothermous. The divergent conclusions concerning its limnetic habit and its vertical distribution will doubtless be found to rest in some cases upon insufficient data, and in others, upon its reactions to varying conditions of light and temperature.

*Eurycercus lamellatus* O. F. Müll.—This species occurred sparingly and irregularly in the winter plankton at minimum temperatures from November 30 to March 28. It is evidently adventitious.

*Ilyocryptus spinifer* Herrick.—Average number, 4. This species occurred sparingly and irregularly in the plankton during the warmer months. The earliest record was on July 23, and the latest October 11 at 65°. This species is evidently adventitious in the plankton. I have doubtfully referred our examples to Herrick's species *I. spinifer*, for the reasons given by Herrick and Turner ('95), rather than to *I. longiremis*, to which Birge ('91) would refer our

American form described by Herrick as *I. spinifer*. A larger amount of material exhibiting a fuller range of variation may, however, serve to connect the two.

*Leptodora hyalina* Lilljeborg.—Average number, 3. This species occurred in small numbers and somewhat irregularly in our collections of channel plankton in summer months. Our earliest record was June 28; and the latest, August 30. It is our largest crustacean planktont and a fairly active swimmer, and was often taken in our tow-nets, which had a larger mouth and coarser mesh (No. 12) than our plankton net. I took this species in great numbers in the upper meter of water at midday in May–June in Lake Meredosia with a seine of No. 000 silk. It may be that it is less abundant in the channel than in the backwaters, and the small number in the plankton collections from the channel may also be accounted for in part by the escape of *Leptodora* from the small orifice (10 cm.) of the plankton net, or to its negative rheotropism when stimulated by the currents of the plankton pump.

*Macrothrix laticornis* Jurine was found in the plankton in May at 64°–73°, adventitious in flood waters.

*Moina micrura* Kurz.—Average number, 261 per m.³ In 1897 it was much more abundant, averaging 5,106 in the more stable conditions of that year.

This is the most abundant of all our *Cladocera*, appearing in great numbers in periods of stable low water during maximum temperatures. It is exceedingly irregular in the extent of its development in different years, the average numbers per m.³ in 1894–1898 being respectively 21,844, 22,842, 188, 5,106, and 261. After making allowances for the irregularity in the number and distribution of the collections in the several years, it still remains apparent that *Moina* is very uneven in its distribution.

The seasonal distribution of *Moina* in channel plankton is confined to July–September with the exception of 9 occurrences in small numbers in the last days of June and the early part of October. The earliest record is June 19, in 1895, when the very large number of 329,448 per m.³ were found,—a degree of development which implies a previous period of multiplication. The first records in subsequent years were all later than this date in June or early in July. After several recurrent pulses, each of 3 to 5 weeks' duration, the numbers decline to a very low level, and the species disappears from the plankton in September–October. In 1898 (Table I.) the last record was made October 11—the latest in any year with the exception of an isolated record October 26, 1897. *Moina micrura* is thus distinctly a summer planktont.

It appears in the plankton only after maximum summer temperatures of approximately 80° have been reached, and decreases rapidly as soon as the autumnal decline passes this point, and soon thereafter vanishes from the plankton. Its optimum temperature in channel waters is thus near 80°.

The relation which hydrographic conditions bear to the appearance of *Moina* in channel plankton appears upon a comparison of the *Moina* population and the movement in river levels in different years, as shown in the following table.

MOINA AND HYDROGRAPHIC CHANGES.

| Year | June | | July | | August | | September | | October | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Avg. No. *Moina* per m.³ | Total movement | Avg. No. *Moina* per m.³ | Total movement | Avg. No. *Moina* per m.³ | Total movement | Avg. No. *Moina* per m.³ | Total movement | Avg. No. *Moina* per m.³ | Total movement |
| 1894 | 192 | 3.4 | 40,415 | 2.1 | 129,880 | 2.6 | 3,677 | 4.7 | 0 | 3.1 |
| 1895 | 329,448 | 2.7 | 91,318 | 7.3 | 2,597 | 3.5 | 87 | 8.8 | 10 | 2.7 |
| 1896 | 0 | 3.4 | 152 | 7.8 | 1,220 | 4.3 | 0 | 3.7 | 0 | 4.6 |
| 1897 | 0 | 6.3 | 1,373 | 5.2 | 1,280 | 2.6 | 70,040 | 0.6 | 605 | 0.6 |
| 1898 | 75 | 4.0 | 660 | 7.4 | 1,496 | 7.5 | 770 | 6.2 | 40 | 3.9 |

While the correlation is not proportionate between the extent of movement in levels and the *Moina* per m.³, it is still very evident that in years of continued and more stable low water *Moina* is found in much greater numbers, as appears on a comparison of 1897 and 1898. It is also confined largely to the more stable part of the year, appearing in 1895 in June–July in large numbers, but falling off when the minor floods of August–September occur, while in 1897 the large numbers are found in the stable levels of August.

The cause of this limitation of *Moina* to periods of low levels in maximum temperatures appears to lie in the food relations of the species. *Moina* abounds in waters approaching stagnation. The slackened current, increased sewage contamination, and excessive growth of the smaller algæ and chlorophyll-bearing flagellates at such seasons in the channel of the Illinois furnish an environment favorable to the great increase in *Moina*, such as was recorded in the low water of July–August, 1894, of June–July, 1895, and of September, 1897, exceeding in each instance that of any other species of *Entomostraca* in the plankton. The relatively smaller numbers of *Moina* at the same seasons in the less contaminated backwaters lends additional support to the view that these conditions approaching stagnation are in a measure responsible for its unusual development in channel plankton.

Of the total *Moina* population, over 65 per cent. are young or immature, 7 per cent. are egg-bearing females,—embryos are often freed from the parent on application of the preserving fluid,—11 per cent. are males, and the remainder, females without eggs. Males appeared with the maximum or decline of the major pulse for the year in 1894 (August), 1895 (July), 1897 (July and September), and 1898 (September), but ephippial females were recorded only in June–July, 1895.

The seasonal distribution of *Moina* conforms to the type of a series of recurrent pulses wherever the numbers are considerable and the collections sufficiently frequent to delineate their courses. Even in the small numbers of 1898 (Table I.) there are suggestions of such pulses.

*Moina micrura* seems to be a species characteristic of the potamoplankton. It is not mentioned as a constituent of the plankton or littoral fauna by any of the various investigators quoted elsewhere in this paper who deal with lakes or ponds in Europe or North America; nor does it appear as a frequent constituent of the potamoplankton elsewhere. Skorikow ('02), indeed, makes the statement, "Bemerkenswert ist für die Flüsse vollständiges Fehlen der Gattung *Moina*." This, however, is hardly the case, for Sowinski ('88) finds it in the plankton of the Tetérew, a tributary of the Dnieper, and Frič and Vávra ('01) report it from the Elbe in 0–1 m. strata in July–September, males appearing in the latter month. Meissner ('02 and '03) also finds it in the Volga at Saratoff, where it "appears almost constantly in the plankton." His investigations, however, appear to cover only the months of May–August. Maximum numbers appeared in July, and considerable differences were noted in two successive years.

I find no previous record of the occurrence of *Moina micrura* in American waters.

*Pleuroxus denticulatus* Birge.—Average number, 5. Occurs in small numbers and irregularly during the autumn and spring months during declining or rising temperatures. The earliest autumnal record is November 2, and the latest, December 15; the earliest vernal is March 8, and the latest is May 31. Egg-bearing females appear in the earlier occurrences in each season. It is evidently adventitious.

*Pleuroxus hamatus* Birge was found once—March 29, 1898.

*Scapholeberis mucronata* O. F. Müll. was recorded in small numbers in May and August–December through the seasonal range of temperatures. It is apparently adventitious in channel plankton, though not attending flood invasions.

*Sida crystallina* O. F. Müll. is rare in the summer plankton.

*Simocephalus serrulatus* Koch.—Average number, 261. This species appears irregularly in the plankton, generally in small numbers and in isolated occurrences. An exception to this is found in May–June, 1898 (Table I.), when it is found continuously May 10–June 14 in numbers which furnish 61 per cent. of the total for all years. There is a slight preponderance of occurrences in May and September, 12 of the 26 recorded appearing in these months. Their irregular appearance in the plankton in general suggests that they are adventitious from the littoral area, especially at times of their maximum development there. The period of their occurrence in the channel plankton in 1898 was one of rising water, 10 to 14 feet above low-water mark—a stage permitting free communication between the channel and large areas of slightly submerged bottom-lands.

*Simocephalus vetulus* O. F. Müll. appeared irregularly and in small numbers in the plankton in April–June (4 occurrences) and September–December (5 occurrences). It is evidently adventitious in the plankton, coming from the littoral area, though not confined to flood waters.

## OSTRACODA.

The species of this order are in the main, during adult life, limicolous forms found in the littoral or bottom ooze or amid the decaying organic matter which accumulates in these regions. The current, the movements of fish and other large aquatic organisms, the action of waves along shore and in shoal regions, all tend to bring these animals into the limnetic fauna. Their centers of distribution are thus in littoral or bottom regions, and in the adult stage they are almost wholly adventitious in the plankton of our waters. In 1898 the average number per $m.^3$ was 191, but in 1897, a more stable year, only 97.

The seasonal distribution of their occurrences in the plankton indicates a decided predominance in March–October, in which months all but 6 of the 73 records were made. In these months from 23 to 82 per cent. of the collections contained *Ostracoda*, while in December–February only 8 to 20 per cent. The percentages in April–September are all above 45 per cent., and the numbers per $m.^3$ are also larger in this period (see Table I.). The tendency toward a vernal increase is apparent in the records of each year in much the form in which it occurs in 1898 (Table I.). The numbers are always small at all seasons, not exceeding 1,600 per $m.^3$ even in the vernal season.

The seasonal distribution is such that the greater part of the occurrences and the greater number of individuals appear in the plankton during the warm season, that is, above 50°. Thus, in 1898 all but 4 of the 24 occurrences and 99.5 per cent. of the individuals appear after the vernal rise passes 50° and before the autumnal decline reaches that point. The *Ostracoda* are planktonts of the warmer season.

It is significant that the *Ostracoda* in our plankton collections are largely young or immature individuals. In 1898, for example, 74 per cent. of individuals observed were not adult, and most of these appeared in April–June. Their occurrence in the plankton can not be traced to the action of flood waters. It thus seems probable that the young *Ostracoda* may temporarily adopt more of a limnetic habit than the adults.

No attempt was made to systematically identify the *Ostracoda* of the plankton catches. The list of species and the notes thereon which follow, are drawn in the main from Sharpe ('97), to whom I am also indebted for assistance in identifications which I have made. A few supplementary notes are based on my plankton records.

DISCUSSION OF SPECIES OF OSTRACODA.

*Candona sigmoides* Sharpe. is rare in shore collections below the plankton station.

*Candona reflexa* Sharpe was taken but once in the river—on November 11.

*Candona simpsoni* Sharpe appears commonly in April–May, and again, in smaller number, in October–November in shore collections on the west side of the river at the plankton station. It is occasionally adventitious in the plankton at these seasons.

*Cypria exsculpta* Fischer appears rarely in the channel plankton and in shore collections in April–October.

*Cypria ophthalmica* Jurine is found frequently in the plankton throughout the year, but more abundantly in May–September, and especially in late summer and early autumn.

*Cypria pustulosa* Sharpe was taken rarely in channel plankton in July and September.

*Cypridopsis vidua* O. F. Müll. was perennial in the plankton, though present in greater numbers in May–October. It is the commonest of the *Ostracoda* in the plankton, and it seems probable that many, though not all, of the young and immature forms belong to this species.

*Limnicythere illinoisensis* Sharpe was taken in the plankton in March, August, and November in 1898, in two instances in flood waters.

COPEPODA.

This is the most abundantly represented order of the *Entomostraca* in channel plankton. Though the species number but 12 to the 25 *Cladocera*, the individuals among the *Copepoda* outnumber the *Cladocera* over fivefold in the grand totals, the ratio varying in individual years from twofold in 1894 to almost sevenfold in 1898.

The average number in 1898 was 40,608 per m.$^3$; in 1897, in more stable conditions, 80,632; in 1896, a year of recurrent floods, 43,764—approximately the number in 1898; in 1895, a year of low water in spring, 116,264—the highest average of any year; and in

1894, 53,149. On June 19, 1895, the *Copepoda* attained a vernal maximum of 1,022,476 per m.³—more than twice the maximum record for any other year.

The *Copepoda* occur in every collection examined, and throughout the whole seasonal range in temperatures. As shown in Table I., the copepodan population during minimum temperatures in December–February is at a minimum, the number per m.³ rising above 10,000 per m.³ in but 6 instances in 44 collections in these months, and falling below 1,000 in but 5. In March–April, as temperatures rise, the numbers increase rapidly, especially after 50° is passed, to a vernal maximum in the last days of April or early in May, usually at the time of the vernal volumetric maximum or very shortly thereafter. In fact, volumetric maxima are generally accompanied by copepodan maxima culminating at the same time or a week later,—as in May, 1898, when the volumetric is on May 3 and the copepodan on May 10.

Numbers continue to be large during the period of summer heat, declining somewhat tardily with the autumnal decline in temperatures. In midsummer in 1898 numbers fall below 20,000 in 9 instances in disturbed hydrographic conditions, but in all previous years in April–September there are only 9 such records in a total of 63. The decline to the winter minimum is usually completed in November, though in 1897, 20,000 is not permanently passed until December 21, at 32°.

The *Copepoda* are thus perennial in the plankton, and the fact that they exhibit a larger winter population than the *Cladocera* is due to the fact that a number of species,—the *Harpacticidæ*, *Cyclops bicuspidatus*, *C. prasinus*, *C. serrulatus*, and *C. modestus* appear to be planktonts belonging to the colder part of the year. As a whole, however, the *Copepoda* reach their greatest quantitative development in the warmer part of the year, with a major pulse in April–May and an occasional autumnal pulse, as in 1897, of equal or greater proportions.

The whole course of the seasonal occurrence of the *Copepoda* as revealed by collections at frequent intervals, exhibits the phenomenon of recurrent pulses at intervals of 3 to 6 weeks, and more clearly defined in stable conditions. Owing to their relatively smaller numbers the adult *Copepoda* do not show the pulse phenomenon as clearly as the nauplii and immature forms. In 1898 the adults form only 10 per cent. of the total.

The relation which hydrographic conditions bear to the copepodan population may be inferred in part from the comparison of years given above, and from the following table, in which are given the average number of *Copepoda* per m.³ and the total monthly movement in river levels in July–December, 1897 and 1898.

| | July | | August | | September | |
|---|---|---|---|---|---|---|
| | 1897 | 1898 | 1897 | 1898 | 1897 | 1898 |
| Average *Copepoda* per m.³........ | 81,543 | 7,720 | 121,070 | 11,080 | 261,387 | 36,920 |
| Total movement in levels, in ft..... | 5.2 | 7.4 | 2.6 | 7.5 | 0.6 | 6.2 |

| | October | | November | | December | |
|---|---|---|---|---|---|---|
| | 1897 | 1898 | 1897 | 1898 | 1897 | 1898 |
| Average *Copepoda* per m.³....... | 128,093 | 28,285 | 49,240 | 10,692 | 15,740 | 7,908 |
| Total movement in levels, in ft.... | 0.6 | 3.9 | 2.2 | 2.6 | 0.5 | 2.4 |

With a total movement of 11.7 ft. in July–December in 1897 and nearly three times as much (30 ft.) in 1898, we find copepodan population falling off to less than one sixth that of the more stable year.

Of the total *Copepoda* in our records for 1894–1899, 78 per cent. are nauplii of *Cyclops* and *Diaptomus*, 13 per cent. are immature *Cyclops*, and the remaining 9 per cent. are *Harpacticidæ*, *Diaptomus*, and adult *Cyclops*. Of the twelve forms, *Cyclops viridis* var. *insectus* is the most important quantitatively, and includes one fourth of the total adult copepodan population, exceeding the next in importance, *C. viridis* var. *brevispinosus*, by over threefold.

The following forms are of numerical importance in the order named: *C. bicuspidatus*, young *Diaptomus*, *Cyclops edax*, *Diaptomus siciloides*, *D. pallidus*, *Canthocamptus* spp., and *Cyclops albidus*. *Cyclops prasinus*, *C. modestus*, *C. phaleratus*, and *C. serrulatus* are also found, but in such small numbers as to be of no quantitative consequence.

DISCUSSION OF SPECIES OF COPEPODA.

*Argulus* sp.—A small and apparently young argulid was found in the plankton on August 10, 1897. Members of this genus are abundant upon *Amia calva* and both species of *Lepisosteus*, all very common fish in channel waters.

*Canthocamptus* spp., including *C. illinoisensis* Forbes.—Average number, 78. *Canthocamptus* was found in the plankton in every month of the year but June. The percentage of collections containing *Canthocamptus* is greatest (44 to 63 per cent.) in March–May and November, and the numbers per m.$^3$ are highest in March–May, when females, females with eggs, and nauplii all occur in their maximum numbers. All records of totals in excess of 400 fall in this vernal period with the single exception of one collection in August, 1897. The largest number, 3,058 per m.$^3$, was found April 29, 1896.

*Canthocamptus* occurs throughout the whole seasonal range in temperatures, with smallest numbers and least regularity during maximum summer heat in June–August. It is thus a planktont of the colder rather than the warmer part of the year.

The relations which hydrographic conditions bear to the occurrence of *Canthocamptus* in the plankton may be inferred from the fact that of the 48 records in 1894–1899, 24 were made in rising flood waters, 14 in falling flood stages within a few days after the culmination of the rise, and but 10 in stable conditions or in declining levels when flood waters of recent origin did not fill the channel. From these facts it seems probable that *Canthocamptus* is in the main adventitious in the plankton from its normal habitat in the slime at the bottom and margins of the river and its backwaters.

Over 88 per cent. of the total *Canthocamptus* recorded in the plankton consists of nauplii. It may be that—as is the case with the young *Ostracoda*—they enter the area of the plankton more readily than the adults. Adults were found in the plankton only in

November–May; females with eggs, only in February–April; and a female with attached spermatophore, in March. Nauplii appear in greatest numbers in April–May, attaining 2,862 per m.$^3$ April 24, 1896, but they rarely rise above 400 per m.$^3$ outside of this vernal period, and are found only in very small numbers in December–March. It appears from our data that the breeding season is principally in April–May.

*Cyclops albidus* Jurine.—Average number, 113; in 1897, 136; in 1896, 33; and in 1894, but 10. A discussion of the variation and synonymy of this species has been published by E. B. Forbes ('97). The species is numerically least important of the dominant members of the genus in our plankton. It was recorded in all months but December and February, but its season is practically confined to April–October, the only exceptions being three records in small numbers in January, March, and November, and two of larger numbers (300 and 200) in the higher temperatures of the delayed autumn of 1897. There is a tendency toward a summer minimum in June–July, with pulses of greater amplitude in April–May and again in August–October. In these months the percentage of collections containing *C. albidus* is highest, being respectively 55, 50, 38, 56, and 53 per cent., and these are the only months in which the numbers per m.$^3$ rise above 600. The highest numbers recorded, 2,862 and 2,400, occurred respectively on April 24, 1896, and October 5, 1897.

Although *C. albidus* is found in the extremes of temperatures, it shows a decided increase after temperatures pass 60° in the vernal rise, and falls off immediately after the autumnal decline passes this point. With high temperatures continued into October, in 1897 we find it continuing in larger numbers. On the other hand, during maximum summer heat (about 80°) numbers, as a rule, fall below 300 per m.$^3$ The temperature optimum thus appears to be in the neighborhood of 70°. The three greatest pulses recorded, occur respectively on April 24, 1896, at 72°; on April 26, 1898, at 57°, and on October 5, 1897, at 71°.

The numbers are too small to exhibit very clearly the phenomenon of recurrent pulses, though the vernal and autumnal pulses are usually well defined, and in the stable conditions of 1897, August, September, October, and November pulses may be traced.

Hydrographic conditions appear to affect *C. albidus* as they do other *Entomostraca*. In July–December, 1897, in stable low water the *C. albidus* population exceeds by over threefold that of these months in 1898.

Of the totals of all records in 1894–1899, 74 per cent. are females,—4 per cent. with eggs and 70 per cent. without,—and the remaining 26 per cent. are males. Immature forms and nauplii were not distinguished from those of other species. Egg-bearing females were recorded only in May and August–October, at times of maximum pulses. Over 82 per cent. of the males were found in August–October—a period of declining temperatures and decreasing food supply.

This is a widely distributed species, though it seems generally to be present in relatively small numbers in the plankton. It occurs in many European lakes. Stenroos ('98) finds that it is the most abundant species of *Cyclops* in Nurmijärvi See, occurring in both the plankton and littoral fauna throughout the summer. Scourfield ('98) finds it common in the waters of Epping Forest, where it is perennial in ponds and small lakes; and Burckhardt ('00) also finds it in the smaller lakes of Switzerland.

It appears to be more generally reported from European streams. Thus, Schorler ('00) finds it to be rare in the plankton of the Elbe at Dresden in May; and Frič and Vávra ('01), perennial in the littoral fauna of the same stream at Podiebrad, while Volk ('03) reports it in the plankton at four of seven localities examined at Hamburg. Meissner ('02 and '03) finds it in May–August in the Volga at Saratoff, where it is abundant in the littoral zone or among vegetation and in quiet backwaters.

Under a variety of synonyms this common and variable species has been reported from many American waters by Herrick ('84) and others. It was described by Professor S. A. Forbes ('90) as *C. gyrinus*, from the plankton of Lake Superior. With the exception of Marsh's record ('95) from Lake St. Clair, it does not elsewhere appear to have been found in the plankton of the Great Lakes. Marsh ('93 and '95) finds it generally in the plankton of smaller bodies of water in Wisconsin and Michigan, and E. B. Forbes ('97) reports it as generally distributed in American waters of a permanent character. Brewer ('98) reports it (as *C. signatus*) in the vernal plankton of deep pools near Lincoln, Neb. No statistical data on its seasonal distribution are given by any of the authors cited.

*C. albidus* appears thus to be adapted to both the littoral and limnetic areas, but seems never to attain great numbers in the latter.

*Cyclops bicuspidatus* Claus.—Average number, 373; in 1897, 206; in 1896, 145; in 1895, 312; and in 1894, only 2. A full discussion of the variation and synonymy of this species has been published by E. B. Forbes ('97).

This species shows sharply marked seasonal limitations. Every one of the 68 records, with the exception of one of a single female found September 30, falls within November–May, and all of the May records were made in the delayed low temperatures of the spring of 1898. The general distribution of this species during this period is indicated by the high percentage of collections in which it was found, viz., 63, 71, 67, 73, 93, 53, and 40, respectively, for November–May. The numbers per $m.^3$ are, however, high only in November and April–May, reaching 8,000 in 1895 and 1898 in this vernal pulse, and 3,560 in November, 1897, in the autumnal pulse. In December–March numbers do not rise above 500 per $m.^3$ save once in December and on March 24–30, 1896. *C. bicuspidatus* is thus a winter and early spring planktont in channel waters of the Illinois.

The temperature adaptations are exhibited by the fact that only 13 of the 68 occurrences are in temperatures above 50°, only 5 above 60°, and but 1 above 70°—that of May 24, 1898, at 73°. On the other hand, the greater developments in numbers take place during these higher temperatures of 50°–70°, the only rises above 1,000 per $m.^3$ at temperatures below 50° being those of March 30 and April 10, 1896, at 48° and 46.4°, and of November 15, 1897, at 47°. Minimum numbers thus prevail below 45°, and the temperature optimum in channel waters of the Illinois appears to lie near 60°.

The seasonal routine in channel waters begins with the appearance of small numbers about November 1, with an occasional pulse of some amplitude in that month followed by a continuance of small numbers through the minimum temperatures of December–February, and a rise with the temperatures in March to a maximum vernal pulse toward the end of April or the first of May, and a complete disappearance of adult individuals after temperatures pass 70° during May–October.

Stable hydrographic conditions appear to favor the increase in *C. bicuspidatus*, as is seen in the large pulse of November 15, 1897 (3,560), and the slight pulse (240) during declining levels in February, 1899.

The vernal development of 1898 (Table I.) is distinctly pulse-like, and there are traces elsewhere of similar phenomena, but in general the numbers of *C. bicuspidatus* are too small to exhibit clearly the phenomenon of recurrent pulses.

Of the totals of all individuals recorded in 1894–1899 I find that 37 per cent. are males, 16 per cent. egg-bearing females, and 47 per cent. females without eggs. Immature forms and nauplii were not distinguished from those of other species. With the exception of a few stragglers, the egg-bearing females were limited principally to March–May. In exceptional cases the males greatly outnumbered the females, as on November 15, 1897, when the ratio was 2,820 to 680.

Though apparently widely distributed, this species does not appear frequently among the planktonts reported from European lakes. Scourfield ('98) reports it as a common species in the waters of Epping Forest throughout the year with the exception of a period of absence or depression in July–August, and Scott ('99) finds it in shore collections made in various months of the year in Scottish lakes, and more abundantly in the warmer months. It has been reported in the potamoplankton in Europe only by Rossinski ('92) from the Moskwa, by Zernow ('01) from the Schoschma, and by Volk ('03) from but one of seven localities in the Elbe at Hamburg.

In American waters, on the other hand, *C. bicuspidatus* is more abundant, and in the Great Lakes it forms a very important part of the plankton. Forbes ('82) finds it (as *C. thomasi*) to be the dominant *Cyclops* in the summer plankton of Lake Michigan and ('90) also abundant in that of Lake Superior. Marsh ('93 and '95) finds it in the summer plankton of the Great Lakes, near Charlevoix, in Lake St. Clair, the Detroit River, and Lake Erie, but only rarely and in small numbers in the smaller bodies of water in Wisconsin and Michigan. E. B. Forbes ('97) extends its recorded range to Massachusetts and to the lakes and rivers of Wyoming, and states that it is widely distributed in America and occurs in large ponds and rivers. Brewer ('98) reports it in the vernal plankton of deep pools near Lincoln, Neb. None of the investigators quoted give statistical data of the seasonal limitations of *C. bicuspidatus*.

The absence of this species from the summer plankton of the Illinois River and its abundance in that of the Great Lakes is perhaps explained by the temperature conditions. Surface waters in Lake Michigan are reported by Ward ('96) to range from 62° to 67° August 11–29, while deeper waters at and below the thermocline reach a minimum of 42°. The warmest waters there (62°–67°) are thus considerably cooler than the coolest in the waters examined by us (which are usually above 70° and often above 80°) during the months in which *C. bicuspidatus* is not found in our plankton. That its absence is not due to sewage contamination in low water which usually prevails during the warmer months is shown by the prompt reappearance of the species in the autumn; as, for example, in 1897, when sewage was even more abundant than usual. It may be that temperature is also one of the factors limiting its distribution elsewhere.

*Cyclops edax* Forbes.—Average number, 49; in 1897, 194; in 1896, 159; in 1895, 321; and in 1894, 187. This is the third species of *Cyclops* in numerical importance in channel plankton of the Illinois.

With the exception of a single record on November 2, 1897, all occurrences of this species in channel plankton are confined to April–October, and all but 9 of the 48 occurrences are in July–October, and 32 of them in July-September—the period of maximum summer heat. During these three months the percentage of collections containing *C. edax* is highest (44 to 75 per cent.), and they are the only months in which the *C. edax* population rises above 1,200 per $m.^3$ in channel waters excepting a single instance on October 5, 1897, in the high temperatures of that delayed autumn. In other months the records are all below 800 and generally below 400 per $m.^3$ The highest number recorded was 3,600 on October 5, 1897.

The seasonal distribution, with maximum numbers in July–September, exhibits a temperature adaptation on the part of *C. edax* to maximum summer temperatures (70° to 80°) in channel waters. An examination of the records shows that only 13 of the 48 records of this species fall in temperatures below 70°, and these were all in the months of April, May, September, October, and November, at times when occurrences were scattering and numbers few; that is, during the rise or decline of the species to or from the summer maximum. Of the 13 records below 70°, there were 5 between 60° and 70°, 7 between 50° and 60°, and but 1 below 50°. *Cyclops edax* in channel waters of the Illinois is thus stenothermic in narrow limits near the maximum temperatures of the year.

The relation which hydrographic conditions bear to the seasonal development of *C. edax* may be inferred from the fact that the July–October population of this species in the disturbed waters of 1898 was only 35 per cent. of that in the more stable months of the preceding year.

The occurrences of *C. edax* take the form of pulses, though less distinctly recurrent and less clearly defined than in species present in larger numbers. Such pulses appear in July, August, and September, 1895, and in August and October, 1897. In 1898 (Table I.) the numbers present are too small to clearly indicate recurrent pulses, though suggestions of the phenomenon appear in the records. In general these pulses tend to coincide with those of other *Entomostraca*.

Of the totals of all our records of *C. edax* in 1894–1899, 60 per cent. are females without eggs; 11 per cent., females with eggs; and 29 per cent., males. Young and nauplii were not distinguished from those of other species. Egg-bearing females were found in April and in June–October, but in greatest numbers in July–August. Males occur in June–November, with no marked predominance in any period.

This species has not been separated from *C. leuckarti* by other investigators of the plankton, though E. B. Forbes ('97), after a careful comparison of American forms with *C. leuckarti* of Europe, concludes that *edax* is specifically distinct, and that *leuckarti* also occurs in American waters, though apparently not in numbers comparable with those in European waters. *C. edax* appears in a measure to replace it in our plankton. He reports it as widely distributed in American lakes and streams and in the plankton of our Great Lakes.

*Cyclops leuckarti* Claus.—A single dead specimen was recorded in channel plankton August 26, 1898. E. B. Forbes ('97) records it from the Fox and Sangamon (tributaries of the Illinois), from the Illinois and Mississippi rivers, and from Quiver, Flag, and Dogfish lakes, backwaters of the Illinois at Havana. It is not, however, at any time a factor of any importance in channel plankton of the Illinois at Havana, being confined to the spring-fed lakes or those shaded by vegetation, where regions of lower temperatures may be found.

This is a widely distributed form in the plankton of European waters. Stenroos ('98) finds it abundant in the plankton of Nurmijärvi See, Scourfield ('98) reports it as common in the waters of Epping Forest in February–October, and Scott ('99) as rare in that of Scottish lakes. Fuhrmann ('00) states that it is always rare in Neuenburger See except in April, and is absent in November–December, while Burckhardt ('00a) finds it to be perennial in Vierwaldstätter See, with breeding season in May–September and maximum in August or September.

It has been generally reported from European streams. Schorler ('00) finds it in the Elbe at Dresden in May–October, with greatest numbers in July–September, and Volk ('03) reports it from four of seven localities in the same stream at Hamburg, though Frič and Vávra ('01) do not find it at Podiebrad. Zykoff ('03), Zernow ('01), and Meissner ('02 and '03) find it in the plankton of Russian rivers. The last author states that it occurs in both channel plankton and littoral fauna among vegetation where breeding females abound during the maximum in May. The young only appear in the channel plankton.

In American waters this species has often been held to include *C. edax*, and the data here quoted from Birge and Marsh refer to the combined species. Marsh ('93 and '95) finds it generally distributed in the lakes of Michigan and Wisconsin, and in the plankton of lakes Erie, Michigan, and St. Clair. Birge ('97) finds it in the summer plankton of Lake Mendota, where it is even more abundant than *C. viridis* var. *brevispinosus.*

*Cyclops modestus* Herrick was recorded in channel plankton only in November, December, and March, in small numbers and isolated occurrences at temperatures of 41° and below. E. B. Forbes ('97) states that this species lives in shallow, weedy water, and has never been found in large numbers, though widely distributed. On account of its relative rarity it may have been overlooked by me and have a wider seasonal distribution than my scanty data indicate.

*Cyclops phaleratus* Koch was recorded in channel plankton only in small numbers in November–December, 1897, at minimum temperatures. E. B. Forbes ('97) states that it is a littoral form, confined to marginal vegetation.

*Cyclops prasinus* Fischer.—Average number, 2. This species occurs sparingly and irregularly in September–March in channel plankton, appearing in largest numbers in the early autumn of 1895 and most continuously in the winter of 1898–99. The numbers are always small, never reaching 400 per $m.^3$, and in 12 of the 17 records falling below 100 per $m.^3$ The percentage of collections containing *C. prasinus* in the totals rises above 20 per cent. only in December (24 per cent.). The seasonal distribution in channel plankton indicates a limitation to the colder part of the year, all records but 5 being below 40°. Nevertheless, in September–October, 1895, the species was recorded in 56°–79°. This fact and its relatively small numbers generally, make it probable that inferences from our scanty data concerning its seasonal distribution can not be conclusive.

Of the totals in all years, 86 per cent. are females without eggs, 6 per cent. females with eggs (found in February and November), and 8 per cent. males.

E. B. Forbes ('97) finds the species widely distributed in American waters from the Great Lakes to roadside pools. Marsh ('93 and '95) finds it (as *C. fluviatilis*) in the larger bodies of water in Wisconsin and Michigan, and in lakes Erie, Michigan, and St. Clair. In Green Lake he ('97) finds it to be the most abundant species of *Cyclops*, and perennial, with maxima in September–November. His statistical data exhibit somewhat irregular numbers which contain suggestions of recurrent pulses such as appear in our records of other species of *Cyclops*. Brewer ('98) finds the species in the plankton of pools near Lincoln, Neb.

*Cyclops serrulatus* Fischer.—Average number, 3. This species was taken sparingly in channel plankton, exhibiting only isolated occurrences in December, January, March, and May, in flood waters at temperatures of 32°–75°. It is much more abundant in Spoon River, where it is sometimes the dominant species of the genus, appearing in May–September, and in small numbers in colder months. It appears to be adventitious in channel plankton of the Illinois River.

This widely distributed *Cyclops* appears but rarely in the records of the plankton of European lakes, and then only in the smaller ones. Stenroos ('98) reports it as abundant in the littoral zone of Nurmijärvi See; and Scourfield ('98) finds it perennial and the most abundant species of *Cyclops* in the waters of Epping Forest.

On the other hand it has been found generally in the plankton of European streams. Zimmer ('99) finds it in the Oder, and Schorler ('00) states that it is abundant in April–June in the plankton of the Elbe at Dresden; Frič and Vávra ('01) find it only in the littoral fauna at Podiebrad; and Volk ('03) in the plankton in four of seven localities in the Elbe at Hamburg. Sowinski ('88) found it in the plankton of the Dnieper, Rossinski ('92) in that of the Moskwa, Zykoff ('00) in the summer plankton of the Volga, and Zernow ('01) in the winter plankton of the Schoschma. Meissner ('02 and '03) reports it in May–August as not abundant in the backwaters and vegetation of the Volga at Saratoff.

In American waters Marsh ('93 and '95) finds it in smaller lakes of Wisconsin and Michigan but not in the Great Lakes, and E. B. Forbes ('97) states that it is one of the most common and widely distributed species in American waters. It appears, however, not to be quantitatively an important element in lake or river plankton. Brewer ('98) finds it to be the most abundant vernal *Cyclops* in the small bodies of water near Lincoln, Neb.

*Cyclops viridis* Jurine.—A synonymy and a discussion of variations in this the dominant and most variable of all the *Cyclops* in our channel plankton, has been given by E. B. Forbes ('97). I have grouped the individuals in our plankton under two varieties, *brevispinosus* Herrick and *insectus* Forbes. The two varieties intergrade, and in my separation I have followed only a single character readily visible without dissection or manipulation, namely, the outer terminal spine of the stylet, which is short, broad, and lance-shaped in *brevispinosus*, and more spine-like in *insectus*. Judging from the results of this method of separation, it appears that this lance-shaped spine is a character of the male in many instances, though not found in all males or limited to this sex.

*Cyclops viridis* var. *brevispinosus* Herrick.—Average number, 124; in 1897, 447; in 1896, 622; in 1895, 850; and in 1894, 68. This form occurred in all months but January, but predominantly from the last days of April to the first week in October, the percentage of collections containing *brevispinosus* in these months being 27, 80, 62, 67, 48, 75, and 59 per cent, respectively, while in other months it does not rise above 20 per cent. The number of individuals is also greater during the warmer season. No record between October 15 and April 20 exceeds 200 per m.$^3$, while between April 20 and October 15 the pulses often culminate at 3,000–5,000 per m.$^3$, and over 98 per cent. of the total individuals were recorded.

This variety appears throughout the whole seasonal range of temperatures from summer's maximum to winter's minimum, but predominantly during the warmer season. Only 15 of the 71 occurrences and 2 per cent. of the individuals were recorded at temperatures below 60°. As soon as the vernal rise in temperatures passes 50°–60°, the minimum numbers and scattered occurrences of the winter months give way to a vernal pulse of considerable magnitude in April–May, attaining 4,452 on April 25, 1895, and 4,960 on May 25, 1897, but only 2,600 on June 7, 1898. This is followed by a period of depression in July, when the summits of the pulses did not often surpass 1,000 per m.$^3$ In the late summer and autumn of 1895 and 1897, and to a less extent in 1896 and 1898, a second period of maximum pulses appears, attaining 9,711 September 12, 1895, and 4,800 October 5, 1898. When temperatures decline in September–October below 50°, this variety falls at once to minimum numbers.

The records of *brevispinosus* in channel plankton exhibit somewhat clearly the phenomenon of recurrent pulses whenever collections at brief intervals make it possible to delimit the pulses. Thus, in 1895 there are pulses culminating in July, August, September, and October; in 1896, in April, May, June, July, August, and September; in 1898, in July, August, and October; but in 1898 (Table I.) the numbers are too small to exhibit fully the phenomenon of recurrent pulses.

The relation to hydrographic conditions may be inferred from the fact that while in the stable conditions of July–October, 1897, pulses culminated at 800–4,800 per m.$^3$, in the same period in the disturbed hydrographic conditions of 1898 no pulse rose above 200 per m.$^3$, and the total of all records in those months is only 8 per cent. of that in 1897. Evidently *brevispinosus* does not thrive in flood waters.

The surprising fact derived from the examination of our records of this variety of *C. viridis*, is that the individuals referred to it are predominantly of the male sex. Out of a total of 74,308, 64,883, or 88 per cent., are males, 8,542, or 11 per cent., females without eggs, and only 883, or one per cent., egg-bearing females. In so far as these data go, they indicate that this so-called species, or even variety, of *C. viridis*, in so far as it is based on the lance-like spine of the stylet, is not well founded. This is, it seems, predominantly a male character, though not exclusively so, since females, and even egg-bearing females, are found which exhibit this structure.

*C. viridis* var. *brevispinosus* appears to be confined to American waters. Marsh ('93 and '95) reports it from the larger lakes of Wisconsin and Michigan, and from the Great Lakes, except Lake Michigan. Birge ('95 and '97) finds that it is the most abundant species of *Cyclops* (except in summer, when *C. leuckarti* abounds) in Lake Mendota, and the only one reproducing under the ice. His data exhibit a major pulse in May, and a second one, of less amplitude, in October, with slight indications of recurrent minor pulses in midsummer, obscured possibly by the massing of his data in fortnightly averages. The seasonal distribution in Lake Mendota is thus much like that in the Illinois River. Marsh ('97) finds the maximum in Green Lake in June at 68°–69°, and only scattering occurrences at other seasons. E. B. Forbes finds this variety widely distributed in American waters, but never especially abundant.

*Cyclops viridis* var. *insectus* Forbes.—Average number, 539; in 1897, 2,115; in 1896, 949; in 1895, 2,966; and in 1894, 905. It is thus more abundant by two- to threefold in the stable years of 1895 and 1897 than in the flood-swept years of 1896 and 1898.

This variety was found in every month of the year, though predominantly in April–October, when the percentages of the collections containing it were respectively 64, 100, 85, 100, 100, 87, and 76 per cent. In November–March the percentages were only 44, 6, 17, 7, and 13. The numbers of individuals are very small, however, from October 1 to April 20, excepting in the autumn of 1897, when, with the delayed high temperatures and the great impetus given to plankton development in the stable conditions of low water, the maximum pulse of all our records, 30,800 per m.$^3$, was reached on October 5, a pulse of 1,200 following in November. With these exceptions no record exceeding 600 per m.$^3$ was made between the dates named. Between April 20 and October 1 the minimum records rarely fall below 600 per m.$^3$, except in 1898, and the pulses often culminate at 2,000–8,000. *C. viridis* var. *insectus* is thus a planktont of the warmer season, and its seasonal distribution is strikingly similar to that of the so-called var. *brevispinosus*.

This form occurs in our plankton throughout the whole seasonal range in temperatures, but only in small numbers and irregularly below 60°. Only 21 per cent. of the collections containing *insectus* were made at temperatures below 60°, and these contained less than 3 per cent. of the total individuals. With the exceptions of the pulses culminating at 43° November 23, 1897, at 1,200 per m.$^3$, and at 57° April 26, 1898, at 4,160 per m.$^3$, no development of this species exceeding 600 per m.$^3$ occurs below 60°. All pulses of more than 3,000 per m.$^3$, excepting only the April pulse of 1898, occur at temperatures above 70°. The species reaches its greatest development in channel waters during the period of maximum temperatures, 70°–80°.

The seasonal distribution of this form shows a few straggling individuals in November–March during temperatures below 50°, and a meteoric rise to a vernal pulse in April–May as this temperature is passed and 60°–70° arrives. This is followed by a series of recurrent pulses, often of considerable amplitude, through September or until temperatures fall below 60°, as in October, 1897. With falling temperatures the drop in numbers to the winter minimum is quickly accomplished. A comparison of the distribution in 1897 and in other years, shows a close correlation between the decline in temperatures and the falling off in numbers of *insectus*.

The relations which hydrographic conditions bear to the development of *insectus* in channel plankton may be inferred from the hydrographs on Plates IX.–XII, Part I., and from the data summarized in the following table,—1894 being omitted because of the incompleteness of the seasonal representation.

In 1895 levels were low, unusually so in the spring, and the flood-free intervals of the year were of more than the usual extent. About 10 feet of the total movement in levels (51.9 ft.) is found in the late December rise. If this is excluded, the total movement falls to 42 feet, and the range in levels to 6.5 feet. Under conditions,

| Year | Range in levels, in ft. | Total movement, in ft. | Average height, in ft., of stage of river | Average number of *insectus* per m.³ |
|---|---|---|---|---|
| 1895 | 12.2 | 51.9 | 3.61 | 2,966 |
| 1896 | 10.1 | 45.7 | 6.98 | 949 |
| 1897 | 14.3 | 44.8 | 6.90 | 2,115 |
| 1898 | 15.5 | 67.2 | 8.02 | 539 |

then, of lowest levels, least range, and total movement, we find the largest development (2,966) of *insectus* in channel plankton.

In 1896 the average river level is much higher, affording increased current and more silt. A series of recurrent floods also flush the channel, though the total movement and range in levels within the limits of the year are not greatly increased. Nevertheless, the changes, which appear mainly below bank-height, affect channel plankton profoundly, and the production of *insectus* falls to 949 per $m.^3$ In 1897 the population rises to 2,115 per $m.^3$, largely as a result of the stable conditions of flood-free waters at low levels and with slight current in the last half of the year. In 1898 the total movement (67.2), range in levels (15.5), and average stage (8.02) reach the extremes in the four years under comparison, and the *insectus* population falls to the lowest level—539 per $m.^3$

A detailed comparison of the July–November period of the two years follows.

| Month | July | | August | | September | |
|---|---|---|---|---|---|---|
| Year | 1897 | 1898 | 1897 | 1898 | 1897 | 1898 |
| Total movement | 5.2 | 7.4 | 2.6 | 7.5 | 0.6 | 6.2 |
| Average stage | 6.05 | 5.70 | 2.29 | 3.66 | 2.01 | 4.44 |
| Average number of *C. viridis* var. *insectus* | 5,093 | 210 | 2,030 | 304 | 2,275 | 325 |

| Month | October | | November | | Average | |
|---|---|---|---|---|---|---|
| Year | 1897 | 1898 | 1897 | 1898 | 1897 | 1898 |
| Total movement | 0.6 | 3.9 | 2.2 | 2.6 | 2.2 | 5.5 |
| Average stage | 2.01 | 4.86 | 2.82 | 7.44 | 3.04 | 5.22 |
| Average number of *C. viridis* var. *insectus* | 8,625 | 200 | 520 | 68 | 3,709 | 221 |

In 1898, with two and a half times the movement in levels found in 1897, the development of *insectus* attains less than 6 per cent. of the numbers reached in the latter year.

The occurrences of *insectus* in channel plankton exhibit the phenomenon of recurrent pulses during the season of its occurrence in large numbers whenever collections are sufficiently frequent to delimit the pulses. Thus, in 1895 there are such pulses in July, August, September, and October; in 1896, in April, June, July, August, and September; in 1897, in July, August, September, October, and November; and in 1898, in April, May, June, July, August, and September, though of slight amplitude in the last three months.

Some of the seeming gaps and irregularities in the series of pulses of *brevispinosus* and *insectus* will be eliminated if the statistics of the two forms are combined in a single series,—a fact which lends support to the view that the two forms belong to the same species, and are parts of a common group of variable organisms.

Steuer ('01) concludes from his examination of the plankton of the Danube at Vienna, based on 19 (?) collections in 15 months, that *Cyclops* has usually two maxima and two minima in each year, and that in the same body of water, owing to various meteorological influences, the two maxima do not in any year fall near each other. The more extensive data at my command show the limitations of such a general conclusion. An examination of the records of individual species of *Cyclops* and of the total *Cyclopidæ* in our waters, make it clear that the major pulses may follow each other at about a monthly interval. For example, in 1897, the total *Cyclopidæ* have their major occurrences in our records as follows, the pulses appearing September 14 and October 5:

| | | | |
|---|---|---|---|
| July 30 | 8,080 | Sept. 14 | 117,000 |
| Aug. 10 | 49,360 | Sept. 21 | 15,260 |
| Aug. 17 | 17,120 | Sept. 29 | 14,400 |
| Aug. 24 | 20,320 | Oct. 5 | 101,600 |
| Aug. 31 | 67,200 | Oct. 12 | 3,400 |
| Sept. 7 | 107,200 | | |

Again, in 1896, the two major pulses of the year are on June 19 (928,984) and July 18 (563,815). Steuer's conclusion seems to be founded upon insufficient data, and can not have general application.

Of the total 240,830 individuals of *C. viridis* var. *insectus* in our records in 1894–1899, 117,166, or 49 per cent., are males; 109,460, or 45 per cent., females without eggs; and 14,204, or 6 per cent., females carrying egg-sacs. If the *brevispinosus* totals are included, the percentages change to 42 per cent. of females—of which 37 per cent. and 5 per cent., respectively, are without and with egg-sacs—and 58 per cent., males. The apparently high proportion of males may be due to the fact that in the enumeration more young females than males were included in the "young" *Cyclops*.

The egg-bearing females were generally more numerous in April–July. No marked predominance in the proportion of males appears at any season in our records.

*Cyclops viridis* does not appear extensively in the plankton literature of European lakes. Stenroos ('98) finds it not rare in the littoral fauna of Nurmijärvi See. Scourfield ('98) reports it as next in abundance to *C. serrulatus* in waters of Epping Forest, where it is perennial. Scott ('99) finds it at all seasons in both littoral and pelagic collections in Scottish lakes, and Amberg ('00) lists it for Katzensee.

It appears but infrequently in the investigations of European streams. Neither Schorler ('00) nor Frič and Vávra ('01) report it from the Elbe, though Volk ('03) lists it from six of seven localities in this stream at Hamburg. Sowinski ('88) finds it in the littoral fauna of the Dnieper, and Zykoff ('03) in the summer plankton of the Volga, though Meissner ('03) states that it is never found in the plankton of that stream at Saratoff, being confined to the littoral zone and to vegetation. No statistical data concerning its seasonal distribution are given by any of these authors, though Meissner states that it reaches its maximum in May in the Volga.

In addition to the species of *Cyclops* here listed for the channel plankton of the Illinois, E. B. Forbes ('97) records in May–September, 1896, *C. varicans* Sars as common, and *C. fimbriatus* var. *poppei* Rehberg and *C. bicolor* Sars as rare.

Owing to the impossibility of separating with certainty the nauplii and young of the various species of *Cyclops* they were all recorded together under the head of "nauplii" and "young *Cyclops*." The former includes also the nauplii of the two species of *Diaptomus* occurring in our plankton.

Young *Cyclops*.—Average number, 4,780; in 1897, 16,035; in 1896, 10,196; in 1895, 21,960; and in 1894, 5,960. With two exceptions in January and February they occur in every collection examined. Numbers are, however, at a minimum in November–March, only 9 instances of more than 1,500 per $m.^3$ appearing in our records in this season. With the exception of two pulses in the autumn of 1897, and two in this season in 1895, all pulses of an amplitude exceeding 8,000 per $m.^3$ are confined to the interval between April 20 and October 1, practically to temperatures above 70°. They also exhibit relations to hydrographic conditions of the same nature as those found in case of the adults of the various species of *Cyclops*, and manifest likewise the phenomenon of recurrent pulses (Table I.). The totals of all young *Cyclops* in 1894–1899 are almost five times those of all adults of the genus. This ratio gives an index of the extent of the decimation by enemies and inimical factors of the environment which exists after the nauplius stage has passed and before that of the adult is reached.

Nauplii of the *Copepoda* (excluding the *Harpacticidæ*).—Average number, 36,707; in 1897, 53,786; in 1896, 24,560; in 1895, 88,442; and in 1894, 45,648. Nauplii were recorded in all collections examined with but two exceptions. As in the case of the adults and young, the large numbers are, however, confined to the warmer season between April 15 and October 1. During the colder months the pulses rarely rise above 20,000 per $m.^3$, and those in excess of 35,000 during these months are with one exception confined to the delayed high temperatures of the stable autumn of 1897. During the warmer season, on the other hand, the pulses frequently attain 100,000 or over.

The maximum record of 928,984 was made in the stable low water of June 19, 1895. All large developments thus lie at temperatures above 70°.

The nauplii bear much the same relation to hydrographic conditions as that found in the adults; for example, in *Cyclops viridis*. This is seen in the fact that in unstable years such as 1896 and 1898 the numbers are on the average only 28 and 68 per cent. of what they were in the more stable conditions of 1895 and 1897, and the average monthly population in July–December in the unstable conditions of 1898 is only 18 per cent. of that in the same months of the previous year.

The relative numbers of adult, young, and larval stages of the *Cyclopidæ* are given in the accompanying table.

| Year | Nauplii | | Young *Cyclops* | | Adult *Cyclops* | |
|---|---|---|---|---|---|---|
| | No. | Ratio | No. | Ratio | No. | Ratio |
| 1894......... | 456,483 | 38 | 59,598 | 5 | 11,726 | 1 |
| 1895......... | 2,741,718 | 19 | 680,749 | 5 | 140,779 | 1 |
| 1896......... | 1,451,524 | 17 | 428,211 | 5 | 84,786 | 1 |
| 1897......... | 1,828,720 | 18 | 545,200 | 5 | 102,730 | 1 |
| 1898......... | 1,908,780 | 30 | 248,576 | 4 | 62,735 | 1 |
| 1899......... | 121,345 | 61 | 5,422 | 3 | | |
| Totals.... | 8,508,570 | 21 | 1,967,756 | 5 | 404,749 | 1 |

The ratios between total adult and young, 1 to 5, are fairly constant in the different years, falling to 1 to 3 in January–March, 1899, and to 1 to 4 in 1898,—a year in which the colder part of the year was most fully represented. This ratio probably represents more truly the relationship of young and adult in the total yearly production. The ratios of adults to nauplii in the several years vary considerably from the totals of all years (1 to 21), rising to 1 to

61 in winter conditions of 1899 (January–March), and falling as low as 1 to 17 in 1896. This was a year of recurrent floods, but its ratio is in sharp contrast with that of 1898 (1 to 30), also a year of considerable hydrographic disturbances during the summer. The adult population was reduced during this year, and especially during the summer floods, but the nauplii do not fall conspicuously below those of other years. It would therefore seem that the deleterious action of flood conditions operates more effectively upon the adult and young than upon the nauplii. This fact may be due to the relative absence of spines and hairs on the nauplii, structures which gather silt and load down the larger forms in the flood waters. The greater number of young and adults in 1896 as compared with 1898 may be due to the more gradual rise of the floods of the former year (see Pl. X. and XII., Pt. I.) and the proportionally greater amount of silt in the more sudden floods of the latter.

The ratios given in the table are of course subject to the error arising from the uneven seasonal distribution of the collections in some years, and to that arising from varying location of the collections on the pulses, especially on those of greatest amplitude. An additional error arises from the leakage of the smaller nauplii through the meshes of the silk net. I have found on experiment that they will thus escape under pressure of a column of water only 3–4 cm. in height. Their dimensions are such that the smaller individuals can pass through the meshes of even the No. 20 silk. It seems probable that ratios of nauplii to adults are actually greater than our records indicate.

The relationship which the pulses of nauplii bear to those of the adult *Cyclopidæ* may be inferred from an examination of the data of Table I. An analysis of the seasonal distribution of the total young and adult *Cyclopidæ* and of the nauplii reveals the fact that in all seasons in which collections at approximately weekly intervals were made, their pulses coincide in a majority of cases in their maxima, and when the coincidences do not occur the maximum of the nauplius pulse appears in the collection of the week following that of the young and adult *Cyclopidæ*. This appears less constantly and clearly in the disturbed hydrographic conditions of 1898 (Table I.) than in the records of more stable years.

Apstein ('96) finds that nauplii of *Copepoda* are most abundant when eggs are most common, and that this bears no constant relation to the abundance of adults. Our collections, extending over longer periods and being at briefer intervals, indicate, however, that this relation does exist. As above stated, the larvæ are most abundant at or shortly after the times of greatest abundance of adults—that is, the maxima of the recurrent pulses. Apstein also states that reproduction is periodic and development rapid. Maximum numbers are reported by him in May and September.

Cohn ('03), on the other hand, maintains that the "innere Logik" and his data show him that the nauplii reach their greatest numbers just prior to the appearance of largest numbers of young and adult *Copepoda*. His data are from 12 collections between May 1 and October 1, and favor his contention in 2 out of 3 cases (of maxima), and both of these lie in collections at intervals of 15 to 16 days. In the light of our data obtained at briefer intervals and the conclusions therefrom that the pulses of larvæ tend to coincide or follow at a brief interval those of the adults, it becomes questionable whether his data are sufficient for his conclusion. His logic also overlooks the fact, apparently, that smaller numbers of *larvæ* might lead to coincident maxima of grown forms during a period of abundant food, on which all pulses must be based, *since the larval stage may be at such times a brief one and the adult a relatively longer one, and the cumulative effect of this relationship would make the conditions shown in our data logically possible.* Furthermore, Cohn used a No. 12 silk in his plankton net, and this allows many nauplii to escape, and probably accounts for the fact that the ratio of larvæ to grown forms in his figures is only 1.3 to 1, while in our records it is 3.5 to 1. The discrepancy arising from this leakage may further tend to weaken his data for his conclusions concerning the relations of larvæ and adults.

Steuer ('01) finds that the nauplii in the Danube at Vienna reach maxima in June and in August, but his data are too scattered to fully delineate their fluctuations. Two out of three of his maxima coincide with those of all *Cyclops*, and the third antedates it (monthly intervals of collection), as in Cohn's data.

*Diaptomus pallidus* Herrick.—Average number per m.$^3$, 11; in 1897, 367; in 1896, 87; in 1895, 152; and in 1894, 146.

This species was recorded in all months of the year but February, though in a larger percentage of the collections and in larger numbers in July–December. Prior to this season the percentage does not rise above 31 per cent., the occurrences are irregular, and the numbers are small. Thus in 1896 and 1898, years of numerous winter and vernal collections, there were but 4 occurrences in each prior to July 1, and all but one of these was of numbers less than 100 per m.$^3$ Only 12 of the 72 occurrences and 8 per cent. of the total individuals were recorded in the first and less stable half of the years. In July–December numbers rise in feebly outlined pulses which attain at the most 800–2,400 per m.$^3$ The percentage of collections containing the species rises to 33–75 per cent., and in stable autumns such as 1895 and 1897 the occurrences are but little interrupted. In its seasonal distribution in channel waters it is thus largely confined to the last—and more stable—half of the year.

Its relationship to hydrographic conditions here suggested also appears in a comparison of the yearly averages given above. The average numbers per m.$^3$ in 1896 and 1898, 87 and 11, are greatly exceeded by those of 1895 (152) and 1897 (367). The total number recorded in July–December in 1897 is 29 times that in 1898. This well-defined predominance in stable seasons, which appears also in the case of the closely related *D. siciloides*, exceeds that of the other *Entomostraca*, and indicates a greater sensitiveness on the part of these species to the deleterious effects of flood waters. The long antennæ and great development of the feathering of the caudal stylets afford a large area for the attachment of the silt and debris of flood waters, and accordingly facilitate the destruction or removal of *Diaptomus* from the plankton more quickly than in the case of *Entomostraca* in which these processes are less developed—as in *Cyclops* or *Bosmina*.

The numbers of individuals are too small to delineate accurately the recurrent pulses which are suggested in the data of distribution. In the autumns of 1895 and 1897, when the occurrences are most continuous, the larger numbers tend to fall at the times of the maxima of pulses of other *Entomostraca*. There is no marked limitation placed upon this species by the seasonal changes in temperature. It is found throughout the seasonal range in temperatures, though numbers are slightly smaller in channel waters in November–December. Nevertheless it occurs in considerable numbers in the backwaters in breeding activity under the ice at minimum temperatures in December.

Of the total individuals, 40 per cent. were males; 45 per cent., females without eggs; and 15 per cent., females with eggs. The sexes show no marked or constant seasonal differences in distribution. Females with eggs are more abundant in August–October, and with spermatophores in the same months. Detached spermatophores were found until December.

This species is stated by Herrick ('84) to be distributed in the entire Mississippi Valley. Marsh ('93) finds it in Wisconsin, but it appears nowhere in the plankton of the Great Lakes. Brewer ('98) reports it in the backwaters of the Platte in Nebraska, and Schacht ('97) states that it is an exceedingly common species in central Illinois, and that it has been reported from Wisconsin, Ohio, and Minnesota. It thus appears to be limited to the shallow and relatively warm waters of the prairie regions of the Mississippi basin.

*Diaptomus siciloides* Lilljeborg.—Average number, 10; in 1897, 350; in 1896, 56; in 1895, 282; and in 1894, 23. As will be seen on comparison, these yearly averages are very similar to those of the preceding species with the exception that the development of *D. siciloides* is about twice that of *D. pallidus* in 1895. In other particulars its seasonal data so resemble those of *D. pallidus* as to make their discussion in large part a repetition. Its seasonal-distribution relations to temperature and hydrographic conditions, breeding season, and its tendency toward a pulse-like recurrence in coincidence with other *Entomostraca* are all very similar to these features in *D. pallidus*. The proportions of the sexes differ slightly, the males being less numerous (31 per cent.) and egg-bearing females more abundant (18 per cent.) than in the previous species.

This is also an American species, reported thus far only from Lake Tulare, Calif., the Illinois River, and waters of Indiana and Iowa (Schacht, '97), and by Brewer ('98) in lakes and pools of Nebraska. It is thus confined largely to shoal and warm waters.

*Diaptomus* spp., immature.—Average number, 19; in 1897, 560; in 1896, 158; in 1895, 336; and in 1894, 120.

The immature individuals of *D. pallidus* and *D. siciloides* were not distinguished from each other in the records. Young *Diaptomus* presumably belonging to these two species occur in every month but March, though but 10 of the 74 records were made in January–June. The percentage of occurrences and the numbers per m.³ are lowest in these months, not rising above 33 per cent. and 500 per m.$^3$ save in two instances. Occurrences of small numbers continue through July, but from August 1 to October 15 appear the major pulses of the year, attaining an amplitude of 1,000 to 8,800 per m.$^3$ With the decline of temperatures in October, numbers fall to levels below 400 per m.$^3$, with one exception (December 14, 1897) at 700. The percentage of occurrences is, however, high (41 to 44 per cent.) and declines only to 33 per cent. in January. The period of greatest numbers of young thus coincides with that of greatest abundance of adults, and lies at temperatures of 70°, and above, in channel waters.

The effect of hydrographic changes upon the occurrence of young *Diaptomus* appears in striking form in the annual averages above quoted. In 1898, a year of sudden changes, the average per m.$^3$ is only 19, while in the stable conditions of the previous year it is 560. The July–December production in 1897 is 28 times greater than that of 1898. In 1896, a year of recurrent but less sudden floods, the average (158) is less than that of 1895 (336), a more stable year. The great reduction of adults noted in 1898 and 1896 is thus paralleled by an even greater reduction of the young.

*Osphranticum labronectum* Forbes occurs in the plankton of Quiver Lake in small numbers (see Schacht, '98), and was found once in channel plankton in June, 1896.

### AMPHIPODA.

*Allorchestes dentata* (Sm.) Faxon.—This is an abundant littoral species found amid vegetation, especially in the vegetation-rich backwaters, such as Quiver Lake. It was not often found in channel plankton, being taken only in the summer of 1895, when the July–August floods carried away the vegetation which had accumulated during the antecedent low water.

## ARACHNIDA.

### ACARINA.

In vegetation-rich backwaters members of the family *Hydrachnidæ* were frequently taken, along with other adventitious organisms, with the plankton. In channel waters they are less frequent, and are represented principally by *Atax*, which is parasitic in great numbers (see Kelly, '99) in the *Unionidæ* which are found in the bottom of the channel. Occurrences in the plankton were limited to the months of May–August, and may be due in part, especially in the warmer months, to the release of the parasites by the death and flotation of their hosts. Flood waters in warm months were often disastrous to the *Unionidæ* because of the load of silt, sewage, and industrial wastes which they carry in channel confines at the lower river stages often prevailing in these months.

Other small aquatic *Acarina* were also present, probably adventitious from the littoral or bottom ooze. With two exceptions their occurrences in the plankton were all in warmer months, April–September, though not in flood waters. During the period of the migration of waterfowl, parasitic *Acarina* were noted in plankton collections in a few instances.

## TARDIGRADA.

*Macrobiotus macronyx* Duj.—Average number, 11. This species is found principally in the colder part of the year, from October to May. The earliest autumnal record was October 30, 1895, at 45°, and the latest vernal one, May 1, 1896, at 68.8°, and the maximum number (2,980 per $m.^3$) was recorded on April 10, 1896, at 46.2°. Of this number, one sixth were females with eggs. Females with eggs were also found in November, February, and March. Because of its seasonal distribution it is found principally, though not solely, in disturbed hydrographic conditions, and its occurrence in the plankton is largely adventitious.

## HEXAPODA.

Owing to the shoal waters, relatively narrow confines, and the hydrographic fluctuations in our fluviatile environment, the aquatic insects, both larval and adult, have many points of contact with the plankton. They constitute a large element in the total volume of the animal population of shore and bottom, and are all connected by chains of food relations, more or less complex and remote, to the plankton organisms or their sources of food. With the single exception of the larvæ of *Corethra* they are all in the main adventitious members of the plankton assemblage, and are much more abundant in the vegetation-rich backwaters than in the channel.

Since the aquatic insects of these collections are being studied by others, with reference to publication in this Bulletin (see Hart, '95, and Needham and Hart, '01), only passing notice of the more important representatives appears in this connection.

### EPHEMERIDA.

Ephemerid larvæ, as a rule in early stages, were found singly or in small numbers in the channel plankton in the warmer months, April–October, at temperatures above 56°. Since these occurrences were with few exceptions in stable hydrographic conditions, it seems probable that the younger larvæ of this order may adopt, at least temporarily, a limnetic habit. Specific identifications of these larvæ were not made.

### HEMIPTERA.

*Corisa* (?) sp.—Average number, 37. A small hemipterous larva doubtfully referred by Mr. C. A. Hart to *Corisa*, was taken with some frequency but in relatively small numbers in the plankton during the summer months. Of the 36 occurrences 27 fall in June–August, 2 in May and 3 in September, 2 in January, and 1 each in October and November. It thus appears in the temperature extremes, but exhibits a great predominance in the season of maximum heat. There is no marked increase in its frequency or numbers in years of more disturbed hydrographic conditions. Its numbers are always small and somewhat erratic. Adult *Corisa*, as well as many other aquatic Hemiptera, were found in plankton collections singly and infrequently.

### DIPTERA.

This group of insects is abundantly represented in the plankton, but in all cases by larval or pupal stages.

*Chironomus* spp., larval stages.—Average number, 124. Larvæ in various stages of development from that immediately after hatching to that approaching pupation were found in channel plankton. They occur in considerable numbers in the ooze in the river bottom, but appear to abandon the limicolous for the limnetic habit, temporarily at least, as a result of hydrographic or other disturbances. There is evidence from their relative numbers in years of different hydrographic conditions that these have considerable influence in bringing them into the plankton. Thus in 1897, in stable conditions, there were only 5 occurrences in 31 collections examined, averaging 88 per $m.^3$, while in 1898, in more disturbed conditions, there were 29 occurrences in 52 collections, averaging 124 per $m.^3$ There is also a marked seasonal distribution. The larvæ appear in the plankton in March–December through the seasonal extremes of temperature, but the numbers in March and November–December are always small. Only 15 per cent. of the occurrences and 5 per cent. of the individuals were found at temperatures below 45°. The percentage of occurrences in the collections is highest in March–September, the percentages being 53, 73, 80, 47, 78, 52, and 50, respectively, to 8 to 35 per cent. during the remaining months.

*Corethra* sp., larval stages.—Average number, 6. These semi-transparent and active larvæ have the characteristics of limnetic organisms, and may be reckoned among the autolimnetic planktonts of our waters. Because of their activity, it seems probable that they escape the drawn net,—especially the small model used by us,—and also, because of their negative rheotaxis, elude the suction of the plankton pump to an even greater extent. Thus, in 1895, in net collections, there were 8 occurrences averaging 32 per $m.^3$ to 4 in 1898, in pump collections, averaging 8 per $m.^3$ *Corethra* larvæ were never abundant in our plankton, probably in part for the reasons just cited. With two exceptions all the occurrences lie in the period of maximum temperatures in June–September, 7 of the 14 occurrences and one third of the individuals being recorded in August.

*Dixa* sp., larval stages.—Average number, 8. Larvæ were recorded singly in scattered occurrences in all months but February and October–December, though most of them appear during maximum temperatures.

Larvæ of *Tanypus* and *Odontomyia* were also recorded in May and June in isolated occurrences.

In addition to the larval stages of these aquatic insects there occurred in the plankton a considerable number of insect eggs, principally those of *Diptera* and *Ephemerida*. These were generally isolated, though sometimes fragments of the egg-string of *Chirono-*

*mus* appeared. They were recorded in all months but February and December, though 20 of the 30 records and 81 per cent. of the individuals appeared in May–August. The numbers are never very large, the maximum record, 5,424 per m.$^3$ on June 29, 1894, being due to a number of fragments of egg-strings.

## MOLLUSCA.

### GASTROPODA.

The adults and young of many of our aquatic gastropods have the habit of gliding on the under side of the surface film of water, and they are also frequently dislodged from their foothold on aquatic vegetation, and thus enter the habitat of the plankton temporarily. This is especially true in vegetation-rich backwaters. The smaller forms, such as *Ancylus*, *Amnicola*, and *Planorbis parvus* were occasionally taken in the summer plankton of the channel.

### LAMELLIBRANCHIATA.

This group is represented in the plankton by the larval stages, or glochidia, of the *Unionidæ*, which form an important part of the bottom fauna of the stream and its tributaries.

*Anodonta corpulenta* Cooper.—Average number of glochidia, 21. The seasonal distribution of the glochidia in the plankton is very well defined. With but two exceptions the 48 occurrences all fall in October–April, and 40 of them in November–March. The occurrences are thus during the period of minimum temperatures; indeed, 31 of the 48 are at temperatures not exceeding 35° in surface waters, and only 9 are above 45°. The earliest autumnal record is September 30, at 58°, and the latest vernal one, June 6, at 79°. Generally the earliest records are in the closing days of September or the early ones of October, and the latest records are about the first of April. The occurrences are more frequent in December–March, the glochidia appearing in 64, 50, 53, and 60 per cent. of the collections, respectively, in these months. Their numbers are also several fold greater at this season than in the earlier and later months of their occurrence. The period of minimum temperatures is thus the season of greatest discharge of glochidia. The numbers are always relatively small, 520 on December 28, 1897, being the maximum record. Their fluctuations are erratic, and show no apparent relation to hydrographic or other environmental changes.

*Lampsilus anodontoides* (Lea) Baker.—Glochidia referred with some uncertainty to this species appeared somewhat irregularly in the plankton in small numbers in September–December and again in June–July. The seasonal distribution in two periods suggests the inclusion of two species.

*Arcidens confragosus* (Say) Simpson.—Glochidia of the type referred by Lea to the old genus *Margaritana*, and presumably belonging to this the commonest member of this genus (as formerly understood) in our locality, were taken in the plankton December 18, 1895, in small numbers.

## BRYOZOA.

This group is represented in our plankton by the floating statoblasts, when these occur, as in *Pectinatella* and *Plumatella*, by detached and floating fragments, as in *Urnatella*, or by natant colonies, as in *Lophopus* and *Cristatella*. Genera such as *Fredericella* and *Paludicella*, whose statoblasts sink, fail to appear in the plankton, though in some cases they may be abundant in the bottom fauna. The *Bryozoa* are plankton feeders, and play an important rôle as plankton reducers in vegetation-rich backwaters.

### DISCUSSION OF SPECIES OF BRYOZOA.

*Cristatella mucedo* Cuvier.—This species was found in the backwaters in summer months, especially in Quiver Lake. Statoblasts probably referable to this species occurred sparingly in May and August.

*Lophopus cristallinus* Pallas.—This rare bryozoan occurred in the channel plankton, though not in our quantitative collections, in July, 1897, in that part of the channel containing the discharge from Quiver Lake. Small, free-swimming colonies of 5–50 zooids were taken in surface waters.

*Pectinatella magnifica* Leidy.—Statoblasts of this superb bryozoan were not uncommon in the backwaters, and were seen several times in the vernal plankton of the channel. The large floating colonies are found near the surface in July–October in the open backwaters, and more rarely in the river itself. The translucent gelatinous cœnœcia are spherical, ellipsoidal, or often somewhat flattened. The longest diameter of these floating masses often exceeds 30 cm.

*Plumatella repens* L.—This is by far the most abundant bryozoan in our locality, being found everywhere on submerged vegetation in the backwaters. It often develops with surprising rapidity on the submerged stems of plants, where, as in 1896, summer floods reinvade the vegetation-covered margins of reservoir backwaters. It is represented in the plankton by its floating statoblasts. Their seasonal distribution shows some correlations with temperature, hydrographic conditions, and the seasonal cycle of the parent organisms. During the period of minimum temperatures (December–February, inclusive) they are relatively rare in the plankton, appearing in 30, 8, and 20 per cent., respectively, of the plankton catches. They are rare in high- as well as low-water conditions, as, for example, in the floods of 1895–96 and 1898, when they appear in but one of 15 collections. With the rise of temperature in March they occur more frequently, as, for instance, in 1898 (Table I.), and continue during the run-off of the spring flood. The occurrences rise in March–May to 60, 46, and 50 per cent. of our total collections in these months, and the numbers also are larger. For example, in 1898, 81 per cent. of the total individuals for the year were found in these months. The discharge from impounding backwaters, the principal breeding grounds of the parent organisms, doubtless tends to increase the numbers of statoblasts in channel plankton during this season. During the remainder of the year, June–November, the percentage of occurrences again falls to 30, 50, 24, 32, 18, and 44 per cent., respectively. The 50 per cent. in July is due to the summer flood of 1896. If this year is omitted the record falls to 33 per cent. The large percentage for November is probably due to the predominantly higher levels of this month, to the invasion of lake margins seeded with statoblasts, and to the increased activity in the fishing industry, which tends to disturb the summer's growth of vegetation in tributary backwaters. The relations to the seasonal cycle of the species are patent. The summer months, June–September, are the season of growth and spread of the parent organisms and of the formation of statoblasts, especially as receding levels expose the water margins. Hydrographic or other disturbances tend to increase the number of statoblasts in the plankton until minimum temperatures are reached, when minimum numbers appear in the plankton. As temperatures rise, the statoblasts tend to float and become more abundant in the plankton, as a result, perhaps, of the physiological and accompanying physical changes in the contents of the statoblast. The declining phase of the major flood of the year is thus the period of greatest flotation and dispersal of the statoblasts.

*Urnatella gracilis* Leidy.—This unique species is found in some abundance on the projecting margins of the shells of the *Unionidæ* which line the river bottom in many reaches of the channel. Small fragments of the colonies containing only several polypides were found in the plankton in May–August and October. The earliest record was May 25, and the latest, October 25, at 48.5°.

## The Periodicity in the Multiplication of the Organisms of the Plankton.

One of the most obvious conclusions brought to light by the detailed study of the volumetric fluctuations of the plankton published in Part I. of this report, and most strongly reinforced by the statistical data showing the fluctuations in the numbers of the individuals of the various species and in the sums total of the various biological groups represented in the limnetic fauna and flora, is that plankton production is fundamentally rhythmic or periodic in character, viewed either in its constituent elements or as a whole. This total result is simply the sum of a like phenomenon pervading more or less completely and coincidently the reproductive cycles, the rise and decline in the numbers of the typical constituents of the plankton. The exceptions to this rhythm are usually found in those organisms which are adventitious in the plankton and have their centers of growth and distribution in other regions than the open water.

Many illustrations of this periodic movement in the multiplication of organisms of the plankton have been cited in the preceding pages and may be seen in the accompanying plates. As an illustration for discussion in detail we may take the pulse of July, 1898, shown in the volumetric data of Table III. and Plate XII. of Part I. The fluctuations in the biological population during this period are also tabulated in Table I. of this paper, and graphically presented in Plates II. and IV., which exhibit the movement in the totals of the *Chlorophyceæ*, *Bacillariaceæ*, and chlorophyll-bearing *Mastigophora*, and of the *Rotifera* and *Crustacea*.

In the volumetric data the pulse rises from a minimum of .14 $cm.^3$ per $m.^3$ on July 5 to a maximum of .88 $cm.^3$ on the 19th, declining again on the 26th to the second minimum, of .67 $cm.^3$ Its duration is thus four weeks and its amplitude, in comparison with many other pulses in the records, relatively slight. It occurs in the more stable conditions of declining river levels and midsummer temperatures. The following list gives the names of the more or less typical planktonts considered in the discussion of this pulse. Others, largely adventitious or insignificant in numbers, might be added to the list. Forms whose antecedent minimum does not fall on June 28 or July 5 are designated by a superior 1; those whose maximum does not fall on July 19 or 26, by a superior 2; and those whose subsequent minimum is not on July 26 or August 2, by a superior 3.

The component forms and groups are *Crenothrix*, etc.[1], total *Schizophyceæ*, *Microcystis ichthyoblabe*[1], total *Chlorophyceæ*, *Actinastrum hantzschii*, *Crucigenia rectangularis*, *Pediastrum boryanum*[1, 2, 3], *P. pertusum*[2, 3], *Raphidium polymorphum*[1], *Scenedesmus genuinus*, *S. obliquus*, *S. quadricauda*, *Schroederia setigera*, total *Bacillariaceæ*[1], *Cyclotella kuetzingiana*, *Diatoma elongatum*[1], *Fragilaria virescens*[2], *Melosira granulata* var. *spinosa*[1], *M. varians*[2], *Navicula* spp., *Synedra acus*, total *Conjugatæ*[1], *Closterium acerosum*, *C. gracilis*, total *Protozoa*, total *Mastigophora*, *Eudorina elegans*, *Euglena acus*, *E. oxyuris*, *E. viridis*, *Glenodinium cinctum*, *Lepocinclis ovum*, *Pandorina morum*[3], *Phacus longicauda*[1, 2, 3], *P. pleuronectes*[2, 3], *Platydorina caudata*, *Pleodorina californica*, *Trachelomonas acuminata*[1], *T. hispida*[3], *T. volvocina*, total *Rhizopoda*, *Difflugia globulosa*, total *Ciliata*[2], *Codonella cratera*[2], *Halteria grandinella*[2, 3], *Tintinnidium fluviatile*[2, 3], total *Rotifera*, total *Bdelloida*[1, 2], total *Ploima*, *Anuræa cochlearis* and var. *tecta*, eggs of *A. cochlearis* and var. *tecta*, *A. hypelasma*, *Asplanchna brightwellii*[1, 2, 3], *Brachionus angularis* and var. *bidens*, eggs of *B. angularis* and var. *bidens*, *B. bakeri* and vars. *cluniorbicularis*[1], *melhemi*, and *tuberculus*[1, 2], total of all varieties of *B. bakeri*, *B. budapestinensis*, *B. militaris*[1, 2], *B. pala* and var. *amphiceros*, *B. urceolaris* var. *bursarius*, *B. variabilis*[2, 3], *Mastigocerca carinata*[1], *Monostyla bulla*, *Polyarthra platyptera*, eggs of *P. platyptera*[2,3], *Rattulus tigris*[2], *Synchæta pectinata*[1], *S. stylata*, eggs of *Synchæta*[1], *Triarthra terminalis*[2, 3], *Pedalion mirum*[1, 3], total *Entomostraca*[1, 3], total *Cladocera*[1, 2, 3], *Bosmina longirostris*[1, 3], *Ceriodaphnia scitula*, *Chydorus sphæricus*, *Diaphanosoma brachyurum*[3], *Moina micrura*[1, 2, 3], total *Copepoda* [1, 2, 3], *Cyclops viridis* var. *brevispinosus* and var. *insectus*, *C. edax*, young *Cyclops*[1], nauplii of *Copepoda*[1, 3].

An examination of the preceding list and of the qualitative data of Table I., reveals the fact that 71 of the more typical planktonts are found in appreciable numbers in the plankton during this month. To this number we may add 6 immature forms separately listed in the table and 14 group totals, making in all 91 sets of statistical data bearing on the components of this pulse. An analysis of the behavior of the constituent species shows that 43 of the 71 species (including varieties and forms), 4 of the 6 immature forms, and 10 of the 14 group totals reach their greatest amplitude on the 19th, coincidently with the volumetric maximum. Thus, in all, a total of 57 out of 91, or 63 per cent., of the sets of data are in precise agreement as to the time of maximum development. Furthermore, of the remaining 35, there are 10 culminating in the collection prior to the 19th (on the 12th), and 16 on the next subsequent one (on the 26th,) in all, 26 or 29 per cent. which culminate on immediately contiguous dates of examination. This leaves a residuum of only about 8 per cent. which do not exhibit precise or substantial agreement as to the time of maximum development. In the matter of the location of antecedent and subsequent minima the agreement is less pronounced, possibly because the enumeration error is relatively greater in the case of minimum numbers. We find, however, that 65, or 72 per cent., of the antecedent minima of the pulses occur on June 28 or July 5, and 71, or 79 per cent., of the subsequent minima are on July 26 or August 2. Nineteen, or 20 per cent., of the antecedent minima are on July 12; and 10, or 11 per cent., of the subsequent ones are on August 12. There is thus a residuum of not over 10 per cent. of instances where the data of species or group totals do not coincide or approximate to this pulse, as described, in position of maximum or one or both of the limiting minima. Considering the necessarily large error entering into our data, it is not surprising that exceptions should occur. Some exceptions—as, for example, that of *Pediastrum pertusum* (Table I.)—are plainly not due to insufficient data, but are apparently normal dislocations; that is, the rhythm of this species at this time is not in harmony with that of the majority of the components of the plankton. But this is only a temporary derangement, and is not the habitual relationship which movement of production in *Pediastrum* bears to that of the plankton as a whole. So, also, many of the *Entomostraca* are much delayed in the culmination of their increase, running over to August 2 or 9, while the most of the other planktonts culminate on July 19 or 26. This lag on the part of the *Entomostraca* is not, however, habitual, as will be seen on examination of Plates II. and IV. This tendency toward a coincident rhythmic movement in production on the part of the constituent organisms of the plankton will be found throughout all the data where collections are of sufficient frequency to adequately delineate the curve of production, that is from July, 1895, to October, 1896, and from July, 1897, to March, 1899, a total of 37 months, and suggestions of a like phenomenon appear in the less complete data of other years. The degree of agreement indicated in the pulse of July, 1898, will be found, on examination of the data in Table I. and in the plates of this paper, to vary with the environmental conditions. Times of rapid change in hydrographic conditions or in temperature generally show less agreement, and more stable conditions will exhibit an equal or even greater uniformity in the prevalence of the pulse-like rise and decline of the component organisms.

In order to show the course of these recurrent pulses in the chlorophyll-bearing planktonts, the total *Chlorophyceæ*, *Bacillariaceæ*, and chlorophyll-bearing *Mastigophora* on the one hand, and of the *Rotifera* and *Entomostraca* ("*Crustacea*" of the plates), I have presented the data graphically on Plates I.–IV., and in the table on pages 296–299 have drawn up a list of the pulses, indicating the dates of the collections which in the main enter into the respective pulses, and the dates of the maxima or culminations of the five groups named. Owing to the irregularities in the data, there are some instances in which several possible dates might have been chosen. Reasons for the choice are in several important instances given in the foot-notes to the table.

It is evident from the data here presented in graphic and tabular form that the pulses of the five groups of organisms tend in the main to coincide. This is shown in Plates I.–IV., and in the fact that the average divergence of 175 group pulses listed in the table is 6.4 days, or, if 5 aberrant instances are omitted, only 4.8 days. In other words, the pulses of the totals of the 5 groups included in the table culminate on an average within an interval of 6.4 (4.8 in 170 cases) days. The average of the extreme limits between maxima of group pulses in the 36 periods of movement listed in the table is 11.7 days.

It is apparent that the pulses would be more completely delineated by collections at daily intervals, but even in the somewhat irregular and at times chaotic data here presented, the evidence seems conclusive that the seasonal production of the dominant species and groups of planktonts tends to fall into coincident recurrent pulses, which, in turn, are the cause of the similar and often coincident volumetric fluctuations.

Attention should be directed to the fact that without any important exceptions this recurrent movement pervades all the organisms of the plankton which are eulimnetic,—such as *Scenedesmus*, *Melosira*, *Trachelomonas*, *Codonella*, *Synchæta*, *Daphnia*, and *Cyclops*,—and often those which at certain seasons become temporary planktonts, such as *Difflugia* and *Hydra*, but not with any regularity the tycholimnetic organisms, such as bdelloid rotifers or nematodes. It affects the more highly organized *Rotifera* and *Entomostraca* with slower growth, longer life, and consequent greater cumulative function as well as the algæ, diatoms, and flagellates, where rapid multiplication, brief existence, and noncumulative (in the individual) function prevail. The large share which the young (eggs and immature stages) play in the pulses of *Rotifera* and *Entomostraca* will be seen in Table I., and repeated attention has been called to this in the discussion of species. The prevalence of breeding females and of eggs or young during the rise of the pulse, and of eggless, moribund, or dead individuals or their skeletons during the decline, is a common phenomenon in all well-defined pulses. No species of plankton organisms appears to escape the operation of this recurrent movement in production.

The proportion of individuals surviving from one pulse to the next is subject to great variation, being often least when the amplitude of the pulses is greatest, and largest when the pulses culminate at slight amplitudes. As a result of periods of minimum development, it follows that the possible length of life of most plankton organisms, even of the *Rotifera* and *Entomostraca*, *in the plankton* must fall within rather narrow limits of a few days or a fortnight at the most. Since the contrasts between minimum and maximum numbers are relatively greater among the chlorophyll-bearing organisms, it follows that the survival proportion is less in these groups.

The *duration* and *amplitude* of the plankton pulses will vary within certain limits according to the method of delineation. The volumetric minima and maxima present the total product in cubic centimeters, and the pulses thus marked out have been described in Part I. They may also be delineated by statistical data of the total plankton or of its larger groups of organisms, or by the domi-

### Comparison of Plankton Pulses and Lunar Cycle.

1895.

| Dates of collections | June 19, July 6, 18, 23, 29 | | Aug. 1, 5, 8, 12, 21, 29 | | Sept. 5, 12, 20, 27 | | Oct. 2, 15, 23, 30 | | Nov. 5, 14, 20, 27 | |
|---|---|---|---|---|---|---|---|---|---|---|
| Dates of full moon | July 6[1] | | Aug. 4 | | Sept. 3 | | Oct. 3 | | Nov. 1 | |
| Pulses | Maximum | Lag | Maximum | Lag | Maximum | Lag | Maximum | Lag | Maximum | Lag |
| Chlorophyceæ | July 6 | 0 | Aug. 21[2] | 17[2] | Sept. 5 | 2 | Oct. 15[2] | 12[2] | Nov. 27 | 26 |
| Bacillariaceæ | " 18 | 12 | " 21 | 17 | " 12 | 9 | " 15 | 12 | " 27 | 26 |
| Mastigophora | " 6 | 0 | " 12 | 8 | " 12 | 9 | " 15 | 12 | " 20 | 19 |
| Rotifera | " 6 | 0 | " 12 | 8 | " 12 | 9 | None | —— | " 14 | 13 |
| Entomostraca | " 18 | 12 | " 21 | 17 | " 20 | 17 | Oct. 15 | 12 | " 27 | 26 |

[1]Maximum and lag of this pulse not clearly defined because of incomplete data.

[2]Pulse of *Chlorophyceæ* (Pl. I.) attains considerable dimensions as early as August 21, but continues its development into the next lunar period, and is consequently assigned to this. It covers the period of three pulses. A slackening in the rapidity of increase on August 21, and in the rate of decline on October 15 may perhaps represent the apices of the submerged pulses of those months.

1895. 1896.

| Dates of collections | Dec. 4, 11, 18, 25, 30 | | Jan. 6, 13, 20, 25 | | Feb 4, 10, 20, 25 | | Mar. 3, 9, 17, 24, 31 | | Apr. 10, 17, 24, 29 | |
|---|---|---|---|---|---|---|---|---|---|---|
| Dates of full moon | Dec. 1 | | Dec. 31 | | Jan. 30 | | Feb. 28 | | Mar. 29 | |
| Pulses | Maximum | Lag | Maximum | Lag | Maximum | Lag | Maximum | Lag | Maximum | Lag |
| Chlorophyceæ | Dec. 11 | 10 | Dec. 30 | + 1 | Feb. 25[3] | 26 | Mar. 17 | 18 | Apr. 29 | 31 |
| Bacillariaceæ | " 18 | 17 | Jan. 6 | 6 | " 4 | 5 | " 17 | 18 | " 24 | 26 |
| Mastigophora | " 11 | 10 | " 6 | 6 | " 10 | 11 | " 17 | 18 | " 29 | 31 |
| Rotifera | " 11 | 10 | " 6 | 6 | " 25 | 26 | None[4] | —— | " 24 | 26 |
| Entomostraca | " 18 | 17 | " 30 | + 1 | None | —— | None[4] | —— | " 24 | 26 |

[3]*Chlorophyceæ* recorded but once in the month.

[4]Pulses of *Rotifera* and *Entomostraca* are apparently submerged in the rising vernal maximum. Slight checks in the rapidity of the rise following March 17 suggest submerged apices at that date.

1896.

| Dates of collections | May 1, 8, 18, 25 | | June 1, 6, 11, 17 | | June 27, July 2, 10, 18, 23 | | July 28, Aug. 3, 8, 15, 21 | | Aug. 26, 29, Sept. 16, 30 | |
|---|---|---|---|---|---|---|---|---|---|---|
| Dates of full moon | April 27 | | May 26 | | June 25 | | July 24 | | Aug. 23 | |
| Pulses | Maximum | Lag | Maximum | Lag | Maximum | Lag | Maximum | Lag | Maximum | Lag |
| Chlorophyceæ | May 18 | 21 | June 17 | 22 | July 18 | 23 | July 28 | 4 | Aug. 26 | 3 |
| Bacillariaceæ | " 18 | 21 | " 11 | 16 | " 18 | 23 | Aug. 8 | 15 | Sept. 16 | 24 |
| Mastigophora | " 18 | 21 | " 11 | 16 | " 18 | 23 | " 15 | 22 | " 16 | 24 |
| Rotifera | " 8 | 11 | " 11 | 16 | " 2 | 7 | " 8 | 15 | None | —— |
| Entomostraca | " 8 | 11 | " 17 | 22 | " 18 | 23 | " 15 | 22 | Sept. 16 | 24 |

1897.

| Dates of collections | June 26, July 14, 21, 30 | | Aug. 3, 10, 17, 24 | | Aug. 31, Sept. 7, 14, 21 | | Sept. 29, Oct. 5, 12, 19, 26 | | Nov. 2, 9, 15, 23, 30 | |
|---|---|---|---|---|---|---|---|---|---|---|
| Dates of full moon | July 13 | | Aug. 11 | | Sept. 10 | | Oct. 9 | | Nov. 8 | |
| Pulses | Maximum | Lag | Maximum | Lag | Maximum | Lag | Maximum | Lag | Maximum | Lag |
| Chlorophyceæ | July 14 | 1 | Aug. 10 | +1 | Sept. 7[5] (" 29) | + 3 (19) | Oct. 19 | 10 | Nov. 23 | 15 |
| Bacillariaceæ | " 14 | 1 | " 17 | 6 | " 29[5] | 19 | " 26 | 17 | " 15 | 7 |
| Mastigophora | " 14 | 1 | " 10 | +1 | " 7 | + 3 | (" 5[5]) " 19 | (+ 4) 10 | " 23 | 15 |
| Rotifera | " 21 | 8 | " 10 | +1 | " 7 | + 3 | " 12 | 3 | " 30 | 22 |
| Entomostraca | " 14 | 1 | " 10 | +1 | " 14 | 4 | " 5 | + 4 | " 23 | 15 |

[5]The pulse of *Chlorophyceæ* is apparently cleft by a falling off in numbers on September 14, resulting in two apices (Pl. II.), one on September 7, and the other on September 29. The *Bacillariaceæ* also exhibit a period of suppression at this time. The extraordinary development of the *Mastigophora* culminating on September 7 (3,199,474,300) and October 5 (6,636,556,000) is due to two enormous pulses of *Carteria multifilis* (2,846,250,000 and 6,476,400,000) which overtop the movement of the rest of the chlorophyll-bearing flagellates and essentially modify their pulse, and, it seems, also depress the coincident and subsequent production of the other chlorophyll-bearing organisms of the plankton. The confusion in the rhythm of the pulses in September–October, 1897, may be due to this unusual development of *Carteria*. Many individuals of *Carteria* in these periods of greatest development were of the pale, almost colorless type, indicating a slight development of chlorophyll. The pulse of *Mastigophora* on October 19 is not shared in by *Carteria*, which exhibits a continuous decline from its maximum on October 5. The pulse of the 19th is, therefore, of the other *Mastigophora*, and hence to be compared with others of the series.

Comparison of Plankton Pulses and Lunar Cycle—*continued*.

| | 1897. | | 1898. | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Dates of collections | Dec. 7, 14, 21, 28 | | Jan. 11, 21, 25 | | Feb. 3, 8, 15, 22 | | Mar. 1, 8, 15, 22, 29 | | April 5, 12, 19, 26 | |
| Dates of full moon | Dec. 8 | | Jan. 7 | | Feb. 6 | | Mar. 8 | | Apr. 6 | |
| Pulses | Maximum | Lag | Maximum | Lag | Maximum | Lag | Maximum | Lag | Maximum | Lag |
| Chlorophyceæ | Dec. 21 | 13 | Jan. 25 | 18 | Feb 8 | 2 | Mar. 22 | 14 | May 3[6] | 27 |
| Bacillariaceæ | " 7 | + 1 | " 21 | 14 | " 15 | 9 | " 22 | 14 | Apr. 26 | 20 |
| Mastigophora | " 21 | 13 | " 11 | 4 | " 22 | 16 | " 22 | 14 | May 3 | 27 |
| Rotifera | 14 | 6 | 25 | 18 | " 22 | 16 | " 22 | 14 | " 3 | 27 |
| Entomostraca | " 14[7] | 6 | " 25 | 18 | " 22 | 16 | " 22 | 14 | Apr. 5 | + 1 |

[6]The April–May period of 1898 appears to exhibit a combination of two pulses in the vernal pulse, the major one of the year. The reasons for regarding this as the combination of two pulses are, (1) the period of time occupied, which is approximately eight weeks, the usual duration of two pulses, and (2) the fact that the curves of the *Bacillariaceæ*, *Mastigophora*, and *Entomostraca* are all more or less bifurcate, suggesting the submergence of two apices.

[7]The December pulse of *Entomostraca* is represented only by a slackening in the rate of decline of the preceding pulse on December 14.



1898.

| Dates of collections | May 3, 10, 17, 24, 31 | | June 7, 14, 21, 28 | | July 5, 12, 19, 26 | | Aug. 2, 9, 16, 23, 30 | | Sept. 6, 13, 20, 27 | |
|---|---|---|---|---|---|---|---|---|---|---|
| Dates of full moon | May 6 | | June 4 | | July 3 | | Aug. 1 | | Aug. 31 | |
| Pulses | Maximum | Lag | Maximum | Lag | Maximum | Lag | Maximum | Lag | Maximum | Lag |
| Chlorophyceæ | May 10 | 4 | June 14 | 10 | July 19 | 16 | Aug. 9[8] | 8 | Sept 27[9] | 27 |
| Bacillariaceæ | " 10 | 4 | " 14 | 10 | " 19 | 16 | " 9 | 8 | " 27 | 27 |
| Mastigophora | " 17 | 11 | " 21 | 17 | " 19 | 16 | " 9 | 8 | " 20 | 20 |
| Rotifera | " 3 | + 3 | " 21 | 17 | " 19 | 16 | " 2 | 1 | " 27 | 27 |
| Entomostraca | " 10 | 4 | " 7 | 3 | " 26 | 23 | " 30 | 30 | " 27 | 27 |

[8]The pulses of August are greatly modified by the hydrographic conditions. The sudden drop in the chlorophyll-bearing organisms on the 16th, the irregularity in and the suppression of any considerable pulse of the *Rotifera*, and the extensive reduction in the *Entomostraca* may all be traced to the repeated flushing of the river by local rains (Pt. I., Pl. VII. and XII.). There were rises of .2 ft. on August 2–3, of .5 ft. on August 6–9, of 3 ft. on August 14–19, and .6 ft. on August 26–27. The greater turmoil in the middle of the month may account for apparent shoving forward of the pulses of the chlorophyll-bearing organisms and that

[9]In the month of September the plankton was again depleted by three repeated rises of about one foot each, the first of which, on September [illegible], caught the ascending September pulse of each of the groups included in the table and in Plates II. and IV., and suppressed it so that the apparent pulse culminates prior to the expected time. The result of the floods is such that we find apparent pulses at the beginning and end of the month and a minimum where a maximum was to be expected.

1898.

| Dates of collections | Oct. 4, 11, 18, 25 | | Nov. 1, 8, 15, 22, 29 | | Dec. 6, 13, 20, 27 | |
|---|---|---|---|---|---|---|
| Dates of full moon | Sept. 29 | | Oct. 29 | | Nov. 27 | |
| Pulses | Maximum | Lag | Maximum | Lag | Maximum | Lag |
| Chlorophyceæ | Oct. 25 | 26 | Nov. 15 | 17 | Dec. 13 | 16 |
| Bacillariaceæ | " 25 | 26 | " 22 | 24 | " 13 | 16 |
| Mastigophora | " 18 | 19 | " 15 | 17 | " 13 | 16 |
| Rotifera | " 25 | 26 | " 15 | 17 | " 20 | 23 |
| Entomostraca | " 25 | 26[10] | " 8 | 10 | " 13 | 16 |

[10]The October pulse of *Entomostraca* is represented only by a slackening in the rate of decline from the preceding pulse. This was a month of some hydrographic instability and of rapid decline in temperatures, both of which factors militate against and retard the development of the pulses.



1899.

| Dates of collections | Jan. 3, 10, 17, 24 | | Jan. 31, Feb. 7, 14, 21, 28 | | Mar. 7, 14, 21, 28 | |
|---|---|---|---|---|---|---|
| Dates of full moon | Dec. 27 | | Jan. 26 | | Feb. 24 | |
| Pulses | Maximum | Lag | Maximum | Lag | Maximum | Lag |
| Chlorophyceæ | Jan. 10 | 14 | Feb. 21 | 26 | Mar. 14 | 18 |
| Bacillariaceæ | " 10 | 14 | " 14 | 19 | " 14 | 18 |
| Mastigophora | " 10 | 14 | " 21 | 26 | " 14 | 18 |
| Rotifera | " 17 | 21 | " 14 | 19 | " 7 | 11 |
| Entomostraca | " 17 | 21 | " 21 | 26 | " 7 | 11[11] |

[11]The disturbed hydrographic conditions of March are responsible for the apparent shoving forward of pulses of *Rotifera* and *Entomostraca* prior to those of the chlorophyll-bearing organisms.

nant or more typical species. In the case of the total plankton some obscurity results at times from the inclusion of unusual proportions of an adventitious population with flood waters. The selection of particular organisms as representative is also subject to some error, since seasonal changes in temperature and other more subtile causes often deflect or suppress their development. The totals of the *Chlorophyceæ*, *Bacillariaceæ*, and chlorophyll-bearing *Mastigophora*, and of the *Rotifera* and *Entomostraca* (Pl. I.–IV.) probably give as complete and accurate a delineation of the recurrent pulses as the statistical data afford, since they include relatively few adventitious organisms, cover the entire year, and swamp more or less completely individual and temporary divergences of particular species. The delineation of the pulses by statistical data is obviously more significant than the volumetric method, since it more clearly presents the results of the reproductive processes which lie at the foundation of the phenomenon of recurrent pulses; and this method is also free from the unavoidable error arising from the presence of silt in the collections.

The interval between collections introduces an error of considerable moment in any effort to determine with accuracy the duration of individual pulses, that is, the length of time between their minima or maxima. Daily collections would render this feasible, but with an interval of a week or more, not only the duration, but in some cases the probable separation of the pulses and location of their maxima, is to some undetermined degree obscured.

The duration of the pulses of the five groups of plankton organisms shown graphically on Plates I.–IV., in the case of all chlorophyll-bearing organisms considered as a whole, is in 29 out of 36 instances between 21 and 35 days, less than 21 in 2 cases, and more than 35 in 5, reaching extreme limits of 14 and 49 days. They average 30.25 days between minima and 29.97 between maxima.

The rotiferan data in the same months may be divided into 36 periods, in 33 of which pulses are traceable. The duration of pulses between minima lies between 21 and 35 days in 23 of the 36 instances, falls below 21 in 5, and is above 35 in 8. The extreme limits are 14 and 49 days.

In the case of the *Entomostraca*, where also the pulses are obscure in a few of the intervals, we find that 22 of the 36 are between 21 and 35 days between minima, 5 are below 21, and 9 are above 35.

The extreme limits are 12 and 49 days, and the average duration is 29.9 days.

From the data here presented it is evident that the pulses are in the main from 3 to 5 weeks in duration, averaging approximately 29 + days—a little less than one calendar month.

The amplitude of the pulses is affected profoundly by seasonal and local influences, such as the factors of temperature and chemical constituents of the water, and the hydrographic conditions. These have been discussed in connection with the volumetric data in Part I. and in the discussion of species in the first part of the present paper. Rising, or even uniform, temperatures, hydrographic stability, decaying vegetation or access of sewage or other fertilizing constituents, all serve to increase the amplitude of the pulses. Declining temperatures, dilution or suspension of access of fertilizers, competition of gross vegetation, access of flood waters and increase in current, all tend, in the main, to depress the *amplitude* of the pulses. The *duration* of the pulses is not, however, thereby essentially modified, though a tendency to override subsequent pulses and partially, rarely wholly, to submerge them is at times of major pulses often apparent in the data.

The *cause* and *significance* of the phenomenon of recurrent pulses is not clearly and unmistakably evident, owing, on the one hand, to the irregularity of the data, and, on the other, to the great complexity of the problem, especially in the fluctuations and varying combinations of environmental factors.

The plankton method itself is subject to great errors, but these are largely distributed, and careful examination, especially of the matter of dilution and computation, has failed to reveal any probable or even possible source *in the method* to which these recurrent pulses can be traced.

It is not impossible that the rhythm here noted is merely a chance outcome of the statistical method and without biological significance; that it is wholly accidental, the resultant of the conflicting and varying factors of the environment and not predominantly or continuously initiated by any one factor. On the other hand, its nature, as we have described it, is such that we are led to look for some factor in the environment with which this rhythm of repetition in growth of the plankton organism might be correlated, or to some internal or inherent factor within the organisms constituting the plankton, or to the interaction of environmental and internal factors.

That there is a periodicity in the reproductive processes of organisms, of both plants and animals, is generally apparent. We see it in the flowering and fruiting seasons of the phanerogams, and in the breeding seasons of many invertebrates, of mollusks and insects, and of the vertebrates generally,—of fishes, amphibians, reptiles, birds, and most mammals. Fluctuations in environmental conditions, notably in food and temperature, influence these reproductive processes. The phenomenon of rise and decline of the microscopic population in laboratory aquaria is likewise an illustration of the periodicity of organisms, but usually within a briefer interval than that of the organisms above mentioned. The studies of Maupas ('88) and Calkins ('02) have shown that even in the seemingly uniform conditions of the laboratory, the reproduction of the ciliate *Protozoa* is essentially periodic.

On *a priori* grounds it seems highly improbable that in the case of the organisms of the plankton, internal factors should determine the coincidence of the periods of growth and reproduction in several hundred species. While it is not impossible, or indeed improbable, that these species of the plankton if bred in pure cultures or *uniform* environment would still exhibit a periodic reproduction, it seems highly improbable that so diverse an assemblage of algæ, diatoms, flagellates, protozoans, rotifers, and entomostracans as is found in the Illinois River, would exhibit in laboratory cultures under uniform conditions any such *coincidence* in the location and duration of their pulses as is found in the waters of the stream. Whatever the internal factors involved in the growth and reproduction of plankton organisms may be, it is patent that we must look for some environmental factor or factors lying at the foundation of the coincidence of seasons of growth and reproduction of plankton organisms, which results in the phenomenon of recurrent pulses in species, groups, and volumetric plankton.

We may simplify the problem somewhat by recognizing at the outset the importance of nutrition in supplying the basis for the periodic growth of any organism. The rotifers and entomostracans, at least the limnetic types, depend in large measure, either directly or indirectly, upon the synthetic planktonts, such as the algæ, diatoms, and flagellates, for their food. Since the pulses of these animal forms (cf. Plates III. and IV. with I. and II.) coincide with or follow shortly after those of the synthetic planktonts on which they feed, we may conclude that the cause of the periodic movement of these animal groups lies in the periodic fluctuations of their food supply. In the causes which control this periodic growth of the chlorophyll-bearing organisms will be found the solution of the general periodic phenomenon in plankton.

This rhythm is primarily one of growth and reproduction, and its solution must be sought in the forms of matter and energy which affect these processes. The nutrition of the chlorophyll-bearing organisms is drawn from matter in the river water. The analyses contained in Part I., Table X., and graphically presented on Plates XLIII. to XLV. trace the seasonal fluctuations in the nitrates—one of the important constituents of plant food. Neither in the seasonal curves of this or other forms of nitrogen delineated in the plates is there any such rhythm of occurrence, though, as has been pointed out in the discussion of the chemical conditions, there are instances of apparent correlation of plankton and nitrate pulses. They occur at irregular intervals, and do not form a continuous series. That there might be a rhythm in the *utilized* nitrates (the analysis represents only the unused residuum) is of course possible, or that it might occur in some other constituent of the food not determined in the analysis is not impossible, but we have no evidence of its existence.

The chlorine in our river waters is a fair index of the amount of sewage or pollution by animal wastes. It is subject to considerable fluctuations, resulting in part from dilution by floods or concentration in low waters, and there are other pulses not traceable to hydrographic conditions, which perhaps result from industrial wastes. These fluctuations in some instances coincide with those of the phytoplankton in question, but the instances are few and the correlation is incomplete. Upon investigation I find that sewage pumpage at Bridgeport, which discharged the sewage of Chicago River into the Illinois and Michigan Canal and thence into the Illinois River, was practically continuous, and could not produce the rhythm in question. The sewage of Peoria has a much more immediate effect upon the chemical conditions in the river at Havana than has that of Chicago. The sewers of this city, I am informed by Mr. H. E. Beasley, City Engineer, are flushed as follows: "The method used is that of flushing with a hose, a crew of men being kept *constantly* at work, taking them about a period of three weeks to cover the entire system. The water is allowed to run through a fire-hose at each point for a period of about ten minutes." This system was in use during the years of our operations, and it offers no occasion for the periodic pulses in growth of the organisms in question. Investigation of the discharges of distillery and cattle-yard wastes into the stream has not revealed any periodic fertilization of the river waters from these sources. The available data thus fail to exhibit any periodic rhythm in *food matters* in solution and suspension in the river water with which these pulses of chlorophyll-bearing organisms might be correlated.

Frequent reference has been made in previous pages to the appearance of pulses upon the decline of floods. Flood waters bring into the river, as shown by the chemical analyses, large quantities of silt and organic wastes in suspension and solution. They inundate great tracts of fertile territory rich in vegetation, and thus add to the available sources of food for the phytoplankton. Decline of the flood affords time for decay and solution of some of the food matters, and time also for breeding, and its run-off adds to the volume of the plankton in channel waters. A comparison of the hydrographs of the years in question (Part I., Pl. X.–XIII.) with these recurrent pulses (Pl. I.) will show that many if not most of the pulses appear on declining flood waters, and that many of the larger ones follow the major floods. Closer analysis, however, shows that there are sometimes two pulses of chlorophyll-bearing organisms on the decline of a single flood, and that they may also occur upon rising flood or even in its entire absence. Floods unquestionably affect the *amplitude* of the pulses, and to some extent *modify their location.* They seem inadequate, however, to explain their recurrence and their tendency toward a uniform interval. Minima between pulses also recur on declining floods.

Energy as well as matter is necessary for the growth of the phytoplankton, and its source is primarily the radiant energy of the sun. A plot of the tri-daily air temperatures at Havana for 1894–1896 (Part I., p. 478, Fig. C) inclusive, exhibits many irregularities, a few of which partake of the nature of recurrent pulses at approximately monthly intervals, but they are too few and too irregular to be the basis of the recurrent growth of the phytoplankton.

The importance of light for the photosynthesis of chlorophyll-bearing plants is unquestioned. The liberation of oxygen by the plant declines as the light fades, and is at its lowest ebb in darkness. The access of light to the phytoplankton is limited by several factors of the environment, principally by silt, which increases the turbidity, and by clouds, which interfere with the penetration of the sun's rays. The fluctuations of the silt are chiefly the result of floods, and, as above stated, the floods do not exhibit a rhythmic pulse which can be correlated with that of the phytoplankton; much less do the periods of rising water which are most silt-laden. The cloudiness of the sky varies greatly at different seasons of the year, being predominant at times in the autumn or winter months. It is subject to pulse-like occurrences of variable duration, but an examination of the records for central Illinois for the years under discussion does not disclose any periodic rhythm which can be correlated continuously with that revealed in the statistical records of the growth of the phytoplankton.

Another factor of the environment which modifies the quantity of light which impinges upon the chlorophyll-bearing organisms of the plankton is the light from the moon. The amount of light, both absolute and relative, derived from this source is not great. According to the calculations of Zöllner, the light from the sun is 618,000 times as bright as that from the full moon. In the present connection it is only important to know whether the moonlight contains an amount of solar energy sufficient to appreciably affect the photosynthesis of the phytoplankton. The amount of such energy utilized in photosynthesis is relatively a small proportion of the total, so that there is a possibility that moonlight may contribute to the process to an appreciable extent.

This matter was investigated by Knauthe ('98), who determined the fluctuations in the gaseous contents of the waters of carp ponds rich in *Euglena*. While this author does not report upon the plankton of the ponds investigated, it seems quite probable that carp ponds rich in *Euglena* would present conditions very similar to those found in the Illinois River, which has a remarkably well-developed *Euglena* water-bloom, and abounds also in carp.

The following table presents the results of his work bearing upon the point in discussion.

Gaseous Contents of Pond Water—(*after Knauthe*).

| 1898 | Source | Light and weather | In 100 cm.³ water | | Remarks |
|---|---|---|---|---|---|
| | | | Cm.³ O | Cm³. $CO_2$ | |
| 4–IX, 2:30 a. m....... | Surface | Still, sky overcast | 0.20<br>0.20 | ——<br>—— | |
| 5–IX, 5:30 a. m....... | Surface | Still, cloudy | 0.71<br>0.71 | 0.97<br>0.97 | |
| 5–IX, 9:00 a. m....... | Surface | After ½ hr. fine rain, still | 1.02<br>1.02 | 0.22<br>0.22 | *Euglena* which 5½ hrs. before still formed a thick film on the surface were now much decreased, but the water was of a very dark green color. |
| 5–IX, 5:00 p. m....... | Surface | After 3 hrs.' sunshine | 2.05<br>2.05 | alkaline | Water taken from surface layer with abundant *Euglena*, and placed, unfiltered, in sunlight. |
| 4–IX, 9:00 p. m....... | Surface | Still and clear, dark | 0.27<br>0.27 | ——<br>—— | Moon not yet risen. |
| 4–IX, 10:30 p. m...... | Surface | Still and clear, moonlight | 0.46<br>0.46 | ——<br>—— | After 1½ hours' illumination by moonlight. |
| 3–X, 9:30 p. m........ | Sammenthiner water | In dark room | 0.24<br>0.24<br>0.23 | ——<br>——<br>—— | |
| 3–X, 9:30 p. m........ | Sammenthiner water | At window in moonlight | 0.42<br>0.43<br>0.43 | ——<br>——<br>—— | |
| 3–X, 11:00 p. m....... | Spandauer water | In dark room | 0.25<br>0.25 | ——<br>—— | |
| 3–X, 11:00 p. m....... | Spandauer water | At window in moonlight | 0.45<br>0.45<br>0.45 | ——<br>——<br>—— | |
| 3–X, 4:00 p. m........ | Spandauer water | Long exposure to bright sunlight | 1.15<br>1.15<br>1.15 | ——<br>——<br>—— | Water had stood in laboratory since 22–IX., and had developed a considerable growth of algæ upon the bottom. |

The amount of oxygen present in the water in the dark, or on dark nights, is reported as 0.20, 0.25, and 0.27 cm.$^3$ per 100 cm.$^3$ of water. In bright sunlight in the laboratory, and with the unusual abundance of *Euglena* due to the collection of the water sample from the region of the water-bloom, it rises to 2.05 cm.$^3$ In the case of the Spandauer samples it rises from 0.25 in the dark to 1.15 (an increase of 0.90 cm.$^3$) after "long" exposure to bright sunlight in the laboratory. The oxygen in this water at 11:00 p. m., after exposure to moonlight, amounted to 0.45, or 0.20 cm.$^3$ more than was found in control water kept in the dark. In this instance the apparent increase due to moonlight is $^2/_9$ of that due to sunlight. In the case of the moonlight the analysis was made at 11:00 p. m., after not more than three hours' exposure. The moon was not at its greatest efficiency, since full moon occurred four days prior to the date of analysis. In the case of the sample exposed to the sunlight the analysis was made at 4:00 p. m., after "langer intens Sonnenschein." It would seem probable that the effectiveness of moonlight in comparison with sunlight in photosynthesis by the phytoplankton here indicated (2 to 9) is below the possible maximum and also above that of the average, since it was obtained when the moon was but four days past its maximum effectiveness.

If we accept Knauthe's data as sufficient to establish the effectiveness of moonlight in increasing photosynthesis, and thus the growth of the phytoplankton, we find in it a recurrent factor of the environment to whose influence we may seek to attribute the rhythm of growth of the chlorophyll-bearing organisms.

On Plates I. and II. I have plotted the seasonal distribution of the totals of the *Chlorophyceæ*, of the *Bacillariaceæ*, and of the *Mastigophora* from July, 1897, to April, 1899, and have indicated the times of full moon throughout this period by marks at the bottom of the diagram. The diagram shows clearly the occurrence of these recurrent pulses, their approximation in the three groups of chlorophyll-bearing organisms upon the same or adjacent dates, and the occurrence of their maxima in some cases at the time of full moon or within an interval of ten days thereafter.

In the table which follows, I have given the data bearing on the pulses of the total of all chlorophyll-bearing organisms from July, 1895, to October, 1896, and from July, 1897, to March, 1899, inclusive, 36 months in all, stating the location of the pulse as determined

RELATION OF PULSES OF CHLOROPHYLL-BEARING ORGANISMS TO LUNAR CYCLE.

| Location of pulse | Interval in days | | Date of maximum | Deviation from day of full moon | | | Date of full moon |
|---|---|---|---|---|---|---|---|
| | Between minima | Between maxima | | Beginning | Maximum | Abscissa of center of gravity | |
| 1895 | | | | | | | |
| July 6 to July 29 | 23 | — | July 18 | 0 | 12 days | + 9.9 | July 6 |
| July 29 to Aug. 29 | 31 | 34 | Aug. 21 | − 6 | 17 " | +11.7 | Aug. 4 |
| Aug. 29 to Sept. 20 | 22 | 22 | Sept. 12 | − 5 | − 9 " | + 7.5 | Sept. 3 |
| Sept. 20 to Oct. 23 | 33 | 29 | Oct. 11 | −13 | 8 " | + 3.8 | Oct. 3 |
| Oct. 23 to Nov. 20 | 28 | 25 | Nov. 5 | − 7 | 4 " | + 8.1 | Nov. 1 |
| Nov. 20 to Dec. 25 | 35 | 36 | Dec. 11 | −10 | 10 " | +11.5 | Dec. 1 |
| Dec. 25 to Jan. 13 | 19 | 19 | Dec. 30 | − 6 | − 1 day | + 1. | Dec. 31 |
| 1896 | | | | | | | |
| Jan. 13 to Feb. 25 | 43 | 36 | Feb. 4 | −17 | 5 days | + 5.1 | Jan. 30 |
| Feb. 25 to Mar. 24 | 27 | 41 | Mar. 17 | − 3 | 17 " | +16.4 | Feb. 28 |
| Mar. 24 to April 29 | 36 | 38 | April 24 | − 5 | 26 " | +22.1 | Mar. 29 |
| April 29 to June 1 | 33 | 24 | May 18 | + 2 | 21 " | +11.6 | April 27 |
| June 1 to June 27 | 26 | 24 | June 11 | + 5 | 16 " | +17.3 | May 26 |
| June 27 to July 23 | 26 | 37 | July 18 | + 2 | 23 " | +20.1 | June 25 |
| July 23 to Aug. 21 | 29 | 21 | Aug. 8 | − 1 | 15 " | + 8.6 | July 24 |
| Aug. 21 to Sept. 30 | 40 | 25 | Sept. 16 | − 2 | 24 " | +18.3 | Aug. 23 |
| 1897 | | | | | | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Aug. 24 to Sept. 14 | 21 | 21 | Sept. 7 | − 7 | − 3 " | − 4.5 | Sept. 10 |
| Sept. 14 to Nov. 2 | 49 | 28 | Oct. 5 | −25 | − 4 " | − 6.3 | Oct. 9 |
| Nov. 2 to Nov. 30 | 28 | 49 | Nov. 23 | − 6 | 15 " | +10.5 | Nov. 8 |
| Nov. 30 to Dec. 21 | 21 | 21 | Dec. 14 | − 9 | 6 " | + 5.1 | Dec. 8 |
| 1898 | | | | | | | |
| Dec. 21 to Jan. 25 | 35 | 28 | Jan. 11 | −17 | 4 " | 0 | Jan. 7 |
| Jan. 25 to Mar. 1 | 35 | 35 | Feb. 15 | −12 | 9 " | + 2.6 | Feb. 6 |
| Mar. 1 to April 5 | 35 | 35 | Mar. 22 | − 7 | 14 " | +10.4 | Mar. 8 |
| April 5 to May 3 | 28 | 35 | April 26 | − 1 | 20 " | +21.6 | April 6 |
| May 3 to May 24 | 21 | 14 | May 10 | − 3 | 4 " | + 3.8 | May 6 |
| May 24 to July 12 | 49 | 35 | June 14 | −11 | 10 " | +14.3 | June 4 |
| July 12 to July 26 | 14 | 35 | July 19 | + 9 | 16 " | +16.3 | July 3 |
| July 26 to Aug. 23 | 28 | 21 | Aug. 9 | − 5 | 8 " | + 9. | Aug. 1 |
| Aug. 23 to Sept. 20 | 28 | 28 | Sept. 6 | − 8 | 6 " | + 4.8 | Aug. 31 |
| Sept. 20 to Oct. 25 | 35 | 21 | Sept. 27 | − 9 | − 2 " | + 5.1 | Sept. 29 |
| Oct. 25 to Nov. 29 | 35 | 56 | Nov. 22 | − 5 | 24 " | +16.5 | Oct. 29 |
| Nov. 29 to Jan. 3 | 35 | 21 | Dec. 13 | + 2 | 16 " | +18.7 | Nov. 27 |
| 1899 | | | | | | | |
| Jan. 3 to Jan. 31 | 28 | 28 | Jan. 10 | + 7 | 14 " | +18.3 | Dec. 27 |
| Jan. 31 to Mar. 7 | 35 | 42 | Feb. 21 | + 5 | 26 " | +21.9 | Jan. 26 |
| Mar. 7 to Mar. 28 | 21 | 21 | Mar. 14 | +11 | 18 " | +20.1 | Feb. 24 |
| Average | 30.25 | 29.97 | | − 5.1 | 11 " | 10.45 | |

in most cases by the delimiting minima, the interval between maxima and that between minima, the date of the maximum, the deviation of the beginning and of the maximum of each pulse from the day of full moon, the deviation of the abscissa of the center of gravity of the polygon formed by the plot of each pulse, and the date of full moon. Deviations prior to the day of full moon are preceded by the minus sign.

The average duration between minima is 30.25 days and that between maxima is 29.97 days; the average location of the initial rise of the pulse is 5.1 days prior to full moon; and the average lags of the dates of maxima and abscissa of center of gravity of the polygon of occurrences are 11 and 10.45 days, respectively. The probable error of the location of the abscissa of a single pulse is ± 7.5 days, and of the average deviation of the abscissa only ± 1.25 days.

The table on pages 296–299 shows the lag of the maximum individual pulses of *Chlorophyceæ*, *Bacillariaceæ*, chlorophyll-bearing *Mastigophora*, *Rotifera*, and *Entomostraca*. The average lag after the day of full moon for each of the groups, in the order named, is 13.7, 14.8, 14.3, 13.1, and 14.3 days, respectively, with a grand average of 14.1 days for the 175 pulses listed. Of these pulses, 135, or 76 per cent., culminate prior to the third week after the date of full moon, and 94, or 52 per cent., in the fortnight between 7 and 21 days after full moon. The averages and percentages given in this paragraph vary but slightly from the demands of chance in favor of a hypothesis that the pulses tend to culminate in a particular part of the lunar month, though the data of the *total* chlorophyll-bearing organisms given above, especially the deviation of the abscissa of center of gravity of the polygon of their occurrences, point in the direction of a lunar factor.

There is no doubt of the fact of recurrent pulses and of their distribution at intervals whose average approximates that of the lunar month, though their correlation with any particular part of the month is in no way constant and much less apparent. It would not be strange that the duration interval, or that the position of maxima and minima, should be subject to disturbance, to acceleration and delay, even to obliteration, in the fluviatile environment with its multitudinous factors,—flood and drouth, summer and winter, clear and turbid waters, bright skies and overcast, the rise and fall of nitrates and other substances in solution or suspension, the fluctuating access of sewage and industrial wastes, the continuous current, the ever-shifting population and the never ceasing struggle for existence and continuance on the part of the interrelated organisms of the plankton and of the shores and bottom. The wonder is that any single factor of the environment, however constant, could make any orderly impression in this chaotic situation.

This fact that the average interval of the pulses of the phytoplankton is so nearly the lunar interval would seem to indicate some causal nexus between the two phenomena. An attempt to correlate the plankton pulse with any particular part of the lunar month is, however, less conclusive. The interval of collection, one week, is so great that the course of the pulse can be traced only approximately, since its beginning, maximum, and end can only, from our data, be located at one of these intervals, and more or less distortion results therefrom. Again, the large error in the plankton method may be responsible for some of the fluctuations in the data. Still more potent, probably, are the various factors of the environment of the plankton which combine with the lunar illumination to produce resultants which divert the pulse more or less from the course which the undisturbed lunar factor would cause it to take. Evidence in favor of this view appears in the fact that the greatest disturbances in the rhythmic sequence of the pulses are wont to occur in winter months, when floods, ice, and cloudy weather tend most to interfere with the full action of the lunar factor, while the correlation of full moon and phytoplankton pulse is most intimate in the stable conditions of summer. This is seen in the fact that the average of the average monthly lags for all of the May–August pulses is 11.9 days, and for the remaining eight months, 18.2 days.

The subject here presented is one which lends itself readily to field and laboratory experiment, and it is to be hoped that the suggestions of a correlation between the plankton pulses and lunar cycle here made, will be put to the test of further quantitative and statistical, as well as experimental, tests in controlled environments where the disturbing factors of the fluviatile environment are eliminated.

## General Considerations on Seasonal Changes.*

It follows from the facts set forth in the preceding discussion that in general each month of the year, characterized by a certain range of hydrographic, thermal, and chemical conditions, and of illumination, has a plankton characterized as follows:—

1. There is a certain range of component species, some of which are occasional stragglers and others more or less uniformly present.

2. There is a certain range of numbers of individuals, varying with the species and profoundly affected by fluctuations in the environmental factors, which change the proportions of the various species from year to year. These proportions vary also from month to month and constitute one of the main elements in the seasonal changes of the plankton.

3. Transitions from month to month are most profound at seasons of greatest environmental change, as, for example, at the times of vernal increase and autumnal decline in temperatures.

4. Seasonal changes in the plankton follow the environmental changes and not the calendar. Autumnal plankton is found when autumnal temperatures arrive.

5. In the main, but two types of plankton are found in the Illinois River—the summer, and the winter assemblage. The vernal and autumnal types are only transitions between the two when organisms from both are present. The winter plankton is characterized by a small number of species peculiar to that season, and a number of perennial forms; the summer, by a larger number of summer organisms with the perennial types.

## Lake versus River Plankton.

Is the plankton of streams (potamoplankton) different from that of lakes (limnoplankton) and ponds (heleoplankton)? This terminology, introduced by Zacharias ('98 and '98a), seems to imply a distinction which lies not only in the differences in the configura-

* The detailed discussion of seasonal changes in the plankton is deferred to a later paper.

tion of the basin and in the matter of movement in the water, but also in the constitution of the plankton itself. The examination of the plankton of the Illinois River, and of its backwaters and tributaries, has shown that the plankton of the channel is not immediately derived from the tributaries, but comes in large part from the impounding backwaters, and at low-water stages is almost exclusively indigenous in the channel itself. Upon the basis of the data from the Illinois River the potamoplankton is distinguished from the other types named by the following characters:—

1. It is a polymixic plankton. This is due to the mingling of planktons from all sources in the drainage basin, especially from tributary backwaters, and the consequent seeding of the channel waters with a great range and variety of organisms. In all of our collections in channel waters monotonic planktons can scarely be said to be present. The nearest approach to such conditions occurred at low-water stages, when channel waters are most fully isolated.

2. It is subject to extreme fluctuations in quantity and constitution. This naturally follows from the manifold factors of the fluviatile environment and the directness with which they impinge upon the plankton. Changes in volume, contact of shore and bottom, access of heat and light, and changes in chemical constituents are frequently both more extensive and more widely effective in the stream than they are in the other types of aquatic environment. In consequence, the plankton of the stream is subject to more catastrophic changes than that of the lake.

3. The potamoplankton is not characterized by any species peculiar to it, nor by any precise assemblages of eulimnetic organisms. It may be distinguished, in a general way only, by the greater proportion of littoral or benthal forms which are mingled with the more typical planktonts.

Zoological Laboratory,
University of California,
May 10, 1904.

# TABLE I.

## Organisms per Cubic Meter in Plankton of Illinois River in 1898.

(An asterisk at head of column indicates that all entries in it are based on filter-paper collections.)

| 1898 | *Crenothrix, Beggiatoa, etc.** | Total *Schizophyceæ* | *Clathrocystis æruginosa* | *Merismopedia glauca* | *Microcystis ichthyoblabe* | *Oscillatoria* spp. | Total *Chlorophyceæ* |
|---|---|---|---|---|---|---|---|
| Jan. 11...... | 399,600,000 | 7,477,200 | 0 | 0 | 7,200,000 | 277,200 | 14,400,200 |
| " 21...... | 105,000,000 | 3,046,800 | 0 | 0 | 3,000,000 | 46,800 | 9,000,200 |
| " 25...... | 10,800,000 | 14,511,837 | 0 | 387 | 14,400,000 | 111,456 | 108,000,386 |
| Feb. 3...... | 575,000,000 | 5,440,000 | 0 | 0 | 5,400,000 | 39,600 | 9,000,500 |
| " 8...... | 275,400,000 | 400 | 0 | 0 | 0 | 400 | 9,014,800 |
| " 15...... | 602,200,000 | 14,800 | 0 | 400 | 0 | 14,400 | 3,600,400 |
| " 22...... | 43,200,000 | 7,200,000 | 0 | 0 | 0 | 9,477 | 3,159 |
| Mar. 1...... | 0 | 0 | 0 | 0 | 0 | 0 | 400 |
| " 8...... | 79,200,000 | 2,700,400 | 0 | 0 | 2,700,000 | 400 | 3,600,400 |
| " 15...... | 40,500,000 | 9,000,600 | 0 | 0 | 9,000,000 | 600 | 22,502,800 |
| " 22...... | 21,600,000 | 9,000,000 | 0 | 0 | 9,000,000 | 0 | 600 |
| " 29...... | 18,900,000 | 6,300,200 | 0 | 0 | 6,300,000 | 200 | 2,704,200 |
| Apr. 5...... | 14,400,000 | 1,800,100 | 0 | 0 | 1,800,000 | 100 | 2,700,300 |
| " 12...... | 21,600,000 | 2,701,100 | 0 | 0 | 2,700,000 | 1,100 | 1,980,100 |
| " 19...... | 21,600,000 | 18,002,400 | 0 | 0 | 18,000,000 | 2,400 | 55,800,800 |
| " 26...... | 10,800,000 | 190,835,200 | 0 | 0 | 190,800,000 | 35,200 | 135,906,400 |
| May 3...... | 42,000,000 | 174,000,000 | 0 | 0 | 168,000,000 | 19,200 | 212,406,400 |
| " 10...... | 7,200,000 | 216,057,600 | 0 | 0 | 216,000,000 | 57,600 | 194,531,200 |
| " 17...... | 14,400,000 | 50,443,200 | 0 | 0 | 50,400,000 | 43,200 | 64,901,200 |
| " 24...... | 7,200,000 | 10,800,000 | 0 | 0 | 9,000,000 | 0 | 12,602,200 |
| " 31...... | 10,800,000 | 14,400,000 | 200 | 0 | 43,200,000 | 200 | 27,001,600 |
| June 7...... | 18,000,000 | 21,600,000 | 0 | 0 | 14,400,000 | 0 | 21,616,000 |
| " 14...... | 18,000,000 | 19,800,000 | 0 | 0 | 3,600,000 | 0 | 46,801,000 |
| " 21...... | 43,200,000 | 43,200,000 | 0 | 0 | 18,000,000 | 0 | 21,658,400 |
| " 28...... | 25,200,000 | 18,000,000 | 0 | 0 | 18,000,000 | 0 | 34,260,800 |
| July 5...... | 50,400,000 | 21,600,040 | 0 | 0 | 21,600,000 | 40 | 9,049,200 |
| " 12...... | 10,800,000 | 28,800,060 | 0 | 0 | 28,800,000 | 60 | 10,851,200 |
| " 19...... | 43,200,000 | 162,000,400 | 400 | 0 | 162,000,000 | 0 | 277,340,400 |
| " 26...... | 7,200,000 | 34,200,000 | 0 | 0 | 34,200,000 | 3,200 | 31,651,600 |
| Aug. 2...... | 21,600,000 | 81,003,200 | 0 | 0 | 79,200,000 | 0 | 45,304,800 |
| " 9...... | 57,600,000 | 1,700,600,000 | 0 | 0 | 1,697,000,000 | 0 | 370,948.400 |
| " 16...... | 21,600,000 | 212,400,800 | 0 | 800 | 208,800,000 | 0 | 68,468,800 |
| " 23...... | 25,200,000 | 100,817,600 | 1,600 | 2,400 | 100,800,000 | 13,600 | 108,200,000 |
| " 30...... | 14,400,000 | 288,121,600 | 800 | 800 | 288,000,000 | 27,200 | 189,334,400 |
| Sept. 6...... | 18,000,000 | 118,800,800 | 800 | 0 | 111,600,000 | 46,400 | 87,489,600 |
| " 13...... | 28,000,000 | 378,013,500 | 0 | 0 | 378,000,000 | 13,500 | 54,042,500 |
| " 20...... | 50,400,000 | 72,008,000 | 0 | 0 | 72,000,000 | 8,000 | 57,684,500 |
| " 27...... | 68,400,000 | 111,614,400 | 0 | 0 | 108,000,000 | 14,400 | 70,526,400 |
| Oct. 4...... | 34,200,000 | 23,400,000 | 0 | 0 | 14,400,000 | 10,500 | 27,024,000 |
| " 11...... | 21,600,000 | 28,803,500 | 0 | 0 | 28,800,000 | 3,500 | 14,420,000 |
| " 18...... | 86,400,000 | 3,600,500 | 0 | 0 | 3,600,000 | 500 | 15,312,500 |
| " 25...... | 1,800,000 | 52,201,560 | 0 | 60 | 52,200,000 | 1,500 | 28,833,000 |
| Nov. 1...... | 93,600,000 | 21,601,000 | 500 | 0 | 21,600,000 | 500 | 14,408,000 |
| " 8...... | 176,400,000 | 10,800,000 | 0 | 0 | 7,200,000 | 0 | 3,604,000 |
| " 15...... | 190,800,000 | 10,400,000 | 0 | 0 | 10,400,000 | 0 | 34,205,000 |
| " 22...... | 124,400,000 | 7,200,000 | 0 | 0 | 7,200,000 | 0 | 16,206,000 |
| " 29...... | 57,600,000 | 7,200,000 | 0 | 0 | 7,200,000 | 0 | 7,205,000 |
| Dec. 6...... | 136,800,000 | 14,400,000 | 0 | 0 | 14,400,000 | 0 | 13,500,000 |
| " 13...... | 468,000,000 | 54,000,000 | 0 | 0 | 54,000,000 | 0 | 84,600,500 |
| " 20...... | 640,800,000 | 59,400,000 | 0 | 0 | 59,400,000 | 0 | 58,500,000 |
| " 27...... | 497,200 | 37,800,000 | 0 | 0 | 37,800,000 | 0 | 27,000,200 |
| Average...... | 55,428,792 | 85,909,984 | 83 | 93 | 83,059,615 | 15,431 | 53,175,104 |

## TABLE I—*continued.*

ORGANISMS PER CUBIC METER IN PLANKTON OF ILLINOIS RIVER IN 1898.

(An asterisk at head of column indicates that all entries in it are based on filter-paper collections.)

| 1898 | *Actinastrum hantzschii** | *Botryococcus braunii* | *Cœlastrum cambricum** | *Crucigenia rectangularis** | *Golenkinia radiata** | *Pediastrum boryanum* | *Pediastrum pertusum* |
|---|---|---|---|---|---|---|---|
| Jan. 11...... | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| " 21...... | 0 | 0 | 0 | 3,000,000 | 0 | 100 | 0 |
| " 25...... | 0 | 0 | 0 | 0 | 0 | 0 | 387 |
| Feb. 3...... | 0 | 0 | 0 | 0 | 0 | 0 | 300 |
| " 8...... | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| " 15...... | 0 | 0 | 0 | 0 | 0 | 0 | 400 |
| " 22...... | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Mar. 1...... | 0 | 0 | 0 | 0 | 0 | 0 | 400 |
| " 8...... | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| " 15...... | 0 | 0 | 0 | 0 | 0 | 600 | 1,800 |
| " 22...... | 0 | 0 | 0 | 0 | 0 | 0 | 800 |
| " 29...... | 0 | 0 | C | 0 | 0 | 600 | 200 |
| Apr. 5...... | 0 | 100 | 0 | 0 | 0 | 0 | 200 |
| " 12...... | 0 | 100 | 0 | 0 | 0 | 0 | 0 |
| " 19...... | 0 | 0 | 0 | 0 | 0 | 400 | 400 |
| " 26...... | 0 | 0 | 0 | 0 | 1,800,000 | 3,200 | 1,600 |
| May 3...... | 0 | 3,200 | 0 | 0 | 7,200,000 | 3,200 | 0 |
| " 10...... | 0 | 0 | 0 | 57,600,000 | 7,200,000 | 6,400 | 4,800 |
| " 17...... | 1,800,000 | 0 | 0 | 0 | 0 | 4,800 | 5,600 |
| " 24...... | 0 | 0 | 0 | 0 | 0 | 600 | 1,600 |
| " 31...... | 0 | 0 | 0 | 5,400,000 | 0 | 1,000 | 600 |
| June 7...... | 0 | 0 | 0 | 0 | 0 | 3,200 | 12,800 |
| " 14...... | 0 | 0 | 1,800,000 | 0 | 0 | 32,000 | 39,400 |
| " 21...... | 0 | 0 | 0 | 0 | 0 | 800 | 56,000 |
| " 28...... | 0 | 0 | 3,600,000 | 0 | 0 | 6,400 | 55,200 |
| July 5...... | 0 | 0 | 0 | 0 | 0 | 3,600 | 44,800 |
| " 12...... | 1,800,000 | 0 | 0 | 0 | 0 | 1,200 | 49,200 |
| " 19...... | 10,800,000 | 0 | 0 | 61,200,000 | 0 | 4,000 | 136,000 |
| " 26...... | 5,400,000 | 0 | 9,000,000 | 1,800,000 | 1,800,000 | 4,000 | 247,600 |
| Aug. 2...... | 3,600,000 | 0 | 0 | 9,000,000 | 0 | 4,800 | 295,200 |
| " 9...... | 5,400,000 | 0 | 10,800,000 | 158,400,000 | 0 | 2,800 | 145,600 |
| " 16...... | 5,400,000 | 0 | 3,600,000 | 18,000,000 | 0 | 1,600 | 66,400 |
| " 23...... | 10,800,000 | 0 | 900,000 | 14,400,000 | 0 | 5,600 | 194,400 |
| " 30...... | 21,600,000 | 0 | 1,800,000 | 21,600,000 | 7,200,000 | 8,000 | 326,400 |
| Sept. 6...... | 10,800,000 | 0 | 0 | 0 | 0 | 12,000 | 177,600 |
| " 13...... | 7,200,000 | 0 | 1,800,000 | 7,200,000 | 0 | 500 | 42,000 |
| " 20...... | 7,200,000 | 0 | 0 | 0 | 0 | 8,500 | 76,000 |
| " 27...... | 0 | 0 | 0 | 1,800,000 | 1,800,000 | 65,600 | 259,200 |
| Oct. 4...... | 1,800,000 | 0 | 0 | 0 | 0 | 5,500 | 18,500 |
| " 11...... | 1,800,000 | 500 | 0 | 3,600,000 | 0 | 8,000 | 11,500 |
| " 18...... | 900,000 | 0 | 0 | 1,800,000 | 0 | 3,500 | 9,000 |
| " 25...... | 5,400,000 | 0 | 0 | 3,600,000 | 0 | 18,500 | 14,500 |
| Nov. 1...... | 1,800,000 | 0 | 0 | 0 | 0 | 5,000 | 3,000 |
| " 8...... | 0 | 0 | 0 | 0 | 0 | 1,000 | 3,000 |
| " 15...... | 0 | 0 | 0 | 3,600,000 | 0 | 3,000 | 3,000 |
| " 22...... | 0 | 0 | 0 | 0 | 0 | 4,000 | 2,000 |
| " 29...... | 0 | 0 | 0 | 0 | 0 | 500 | 0 |
| Dec. 6...... | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| " 13...... | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| " 20...... | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| " 27...... | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Average...... | 199,038 | 75 | 640,384 | 7,153,846 | 519,231 | 4,510 | 44,372 |

# TABLE I—*continued.*

## Organisms per Cubic Meter in Plankton of Illinois River in 1898.

(An asterisk at head of column indicates that all entries in it are based on filter-paper collections.)

| 1898 | *Raphidium polymorphum** | *Scenedesmus genuinus** | *Scenedesmus obliquus** | *Scenedesmus quadricauda** | *Schroederia setigera** | *Selenastrum bibraianum* |
|---|---|---|---|---|---|---|
| Jan. 11...... | 0 | 0 | 0 | 0 | 14,400,000 | 0 |
| " 21...... | 0 | 0 | 0 | 0 | 6,000,000 | 0 |
| " 25...... | 0 | 0 | 0 | 3,600,000 | 7,200,000 | 0 |
| Feb. 3...... | 0 | 0 | 0 | 0 | 9,000,000 | 0 |
| " 8...... | 0 | 0 | 0 | 0 | 9,000,000 | 0 |
| " 15...... | 0 | 0 | 0 | 3,600,000 | 43,200,000 | 0 |
| " 22...... | 0 | 0 | 0 | 0 | 0 | 0 |
| Mar. 1...... | 0 | 0 | 0 | 0 | 0 | 0 |
| " 8...... | 900,000 | 0 | 0 | 900,000 | 1,800,000 | 0 |
| " 15...... | 5,400,000 | 0 | 0 | 0 | 17,100,000 | 0 |
| " 22...... | 16,200,000 | 0 | 0 | 0 | 7,200,000 | 0 |
| " 29...... | 0 | 0 | 0 | 0 | 2,700,000 | 0 |
| Apr. 5...... | 0 | 0 | 0 | 900,000 | 1,800,000 | 0 |
| " 12...... | 0 | 0 | 0 | 1,800,000 | 0 | 0 |
| " 19...... | 7,200,000 | 0 | 0 | 1,800,000 | 46,800,000 | 0 |
| " 26...... | 0 | 0 | 900,000 | 13,500,000 | 108,000,000 | 0 |
| May 3...... | 24,000,000 | 1,800,000 | 0 | 23,400,000 | 150,000,000 | 0 |
| " 10...... | 7,200,000 | 0 | 1,800,000 | 70,200,000 | 50,400,000 | 0 |
| " 17...... | 7,200,000 | 0 | 0 | 34,200,000 | 21,600,000 | 0 |
| " 24...... | 3,600,000 | 0 | 0 | 5,400,000 | 3,600,000 | 0 |
| " 31...... | 3,600,000 | 0 | 0 | 3,600,000 | 14,400,000 | 0 |
| June 7...... | 9,000,000 | 0 | 900,000 | 1,800,000 | 9,000,000 | 0 |
| " 14...... | 21,600,000 | 0 | 900,000 | 0 | 21,600,000 | 0 |
| " 21...... | 0 | 0 | 0 | 7,200,000 | 10,800,000 | 0 |
| " 28...... | 1,800,000 | 0 | 0 | 10,800,000 | 10,800,000 | 0 |
| July 5...... | 1,800,000 | 1,800,000 | 0 | 1,800,000 | 3,600,000 | 0 |
| " 12...... | 1,800,000 | 900,000 | 0 | 4,500,000 | 1,800,000 | 0 |
| " 19...... | 75,600,000 | 3,600,000 | 10,800,000 | 79,200,000 | 25,200,000 | 0 |
| " 26...... | 5,400,000 | 0 | 1,800,000 | 900,000 | 1,800,000 | 0 |
| Aug. 2...... | 7,200,000 | 0 | 0 | 9,000,000 | 12,600,000 | 1,800,000 |
| " 9...... | 57,600,000 | 19,800,000 | 36,000,000 | 39,600,000 | 28,800,000 | 1,800,000 |
| " 16...... | 7,300,000 | 7,200,000 | 1,800,000 | 12,600,000 | 7,200,000 | 3,600,000 |
| " 23...... | 1,800,000 | 0 | 900,000 | 17,100,000 | 46,800,000 | 900,000 |
| " 30...... | 18,000,000 | 3,600,000 | 2,700,000 | 54,000,000 | 46,800,000 | 7,200,000 |
| Sept. 6...... | 900,000 | 0 | 8,100,000 | 12,600,000 | 50,400,000 | 3,600,000 |
| " 13...... | 0 | 0 | 3,600,000 | 16,200,000 | 10,800,000 | 1,800,000 |
| " 20...... | 7,200,000 | 0 | 0 | 5,400,000 | 28,800,000 | 0 |
| " 27...... | 10,800,000 | 0 | 3,600,000 | 12,600,000 | 28,800,000 | 0 |
| Oct. 4...... | 5,400,000 | 900,000 | 900,000 | 7,200,000 | 9,000,000 | 1,800,000 |
| " 11...... | 0 | 0 | 0 | 5,400,000 | 3,600,000 | 0 |
| " 18...... | 1,800,000 | 0 | 0 | 4,500,000 | 5,400,000 | 900,000 |
| " 25...... | 0 | 0 | 1,800,000 | 10,800,000 | 7,200,000 | 0 |
| Nov. 1...... | 0 | 0 | 0 | 1,800,000 | 10,800,000 | 0 |
| " 8...... | 0 | 0 | 0 | 1,800,000 | 0 | 0 |
| " 15...... | 3,600,000 | 0 | 1,800,000 | 0 | 21,600,000 | 3,600,000 |
| " 22...... | 3,600,000 | 0 | 0 | 1,800,000 | 10,800,000 | 0 |
| " 29...... | 0 | 0 | 0 | 0 | 7,200,000 | 0 |
| Dec. 6...... | 0 | 0 | 0 | 0 | 12,600,000 | 0 |
| " 13...... | 0 | 0 | 0 | 900,000 | 82,800,000 | 0 |
| " 20...... | 0 | 900,000 | 0 | 0 | 57,600,000 | 0 |
| " 27...... | 0 | 0 | 0 | 0 | 27,000,000 | 0 |
| Average...... | 61,230,769 | 778,846 | 1,505,769 | 9,276,923 | 21,450,000 | 519,235 |

## TABLE I—*continued.*

### ORGANISMS PER CUBIC METER IN PLANKTON OF ILLINOIS RIVER IN 1898.

(An asterisk at head of column indicates that all entries in it are based on filter-paper collections.)

| 1898 | Total *Bacillariaceæ* | *Asterionella gracillima* | *Cyclotella kuetzingiana** | *Diatoma elongatum* var. *tenue** | *Fragilaria crotonensis* | *Fragilaria virescens* |
|---|---|---|---|---|---|---|
| Jan. 11...... | 239,580 | 146,280 | 0 | 0 | 0 | 10,000 |
| “ 21...... | 49,003,100 | 1,200 | 3,000,000 | 12,000,000 | 0 | 0 |
| “ 25...... | 3,774,901 | 10,620 | 0 | 0 | 0 | 29,025 |
| Feb. 3...... | 9,268,530 | 5,500 | 0 | 120,000 | 3,180 | 11,250 |
| “ 8...... | 7,464,880 | 17,200 | 0 | 60,000 | 0 | 0 |
| “ 15...... | 29,266,000 | 12,000 | 7,200,000 | 200,000 | 0 | 0 |
| “ 22...... | 21,911,653 | 0 | 0 | 14,400,000 | 0 | 78,975 |
| Mar. 1...... | 11,850,400 | 0 | 0 | 3,600,000 | 0 | 0 |
| “ 8...... | 9,080,800 | 0 | 0 | 0 | 0 | 0 |
| “ 15...... | 24,342,400 | 3,200 | 8,100,000 | 4,500,000 | 3,000 | 130,000 |
| “ 22...... | 42,589,120 | 5,920 | 16,200,000 | 0 | 0 | 161,600 |
| “ 29...... | 18,693,300 | 17,000 | 10,800,000 | 0 | 0 | 72,500 |
| Apr. 5...... | 8,760,120 | 42,320 | 900,000 | 60,000 | 0 | 15,600 |
| “ 12...... | 36,990,300 | 170,500 | 22,500,000 | 0 | 19,920 | 40,000 |
| “ 19...... | 794,044,320 | 24,059,000 | 725,400,000 | 0 | 19,920 | 40,000 |
| “ 26...... | 3,453,778,080 | 891,648,000 | 2,880,000,000 | 1,800,000 | 374,080 | 200,000 |
| May 3...... | 2,583,832,560 | 197,683,200 | 891,000,000 | 18,000,000 | 924,800 | 390,000 |
| “ 10...... | 3,865,257,360 | 27,175,680 | 2,668,000,000 | 10,800,000 | 14,469,120 | 255,960,000 |
| “ 17...... | 1,795,608,400 | 19,699,200 | 1,260,000,000 | 14,400,000 | 388,800 | 4,110,400 |
| “ 24...... | 43,487,480 | 15,080 | 18,000,000 | 1,800,000 | 0 | 1,504,800 |
| “ 31...... | 138,879,370 | 362,880 | 88,200,000 | 1,800,000 | 0 | 587,450 |
| June 7...... | 182,162,000 | 3,283,200 | 55,800,000 | 0 | 0 | 434,000 |
| “ 14...... | 1,039,619,680 | 336,194,880 | 46,800,000 | 0 | 0 | 404,000 |
| “ 21...... | 340,702,200 | 100,320 | 0 | 0 | 0 | 199,800 |
| “ 28...... | 350,220,000 | 34,560 | 291,000,000 | 1,800,000 | 0 | 220,000 |
| July 5...... | 135,090,000 | 3,840 | 50,400,000 | 1,800,000 | 0 | 50,000 |
| “ 12...... | 127,576,000 | 0 | 72,000,000 | 900,000 | 0 | 120,000 |
| “ 19...... | 788,521,600 | 0 | 561,600,000 | 3,600,000 | 0 | 0 |
| “ 26...... | 87,702,400 | 0 | 63,000,000 | 0 | 0 | 0 |
| Aug. 2...... | 111,750,400 | 4,800 | 54,000,000 | 0 | 0 | 0 |
| “ 9...... | 443,526,000 | 1,200 | 401,400,000 | 3,600,000 | 0 | 0 |
| “ 16...... | 115,018,656 | 0 | 97,200,000 | 0 | 0 | 0 |
| “ 23...... | 180,994,200 | 0 | 122,400,000 | 0 | 0 | 0 |
| “ 30...... | 209,793,200 | 2,400 | 93,600,000 | 2,700,000 | 0 | 0 |
| Sept. 6...... | 186,870,800 | 0 | 115,200,000 | 0 | 0 | 0 |
| “ 13...... | 167,208,500 | 0 | 66,400,000 | 0 | 0 | 6,000 |
| “ 20...... | 87,481,000 | 0 | 3,600,000 | 0 | 0 | 0 |
| “ 27...... | 215,018,800 | 0 | 57,600,000 | 0 | 0 | 0 |
| Oct. 4...... | 131,418,900 | 0 | 37,800,000 | 0 | 0 | 0 |
| “ 11...... | 46,930,350 | 0 | 7,200,000 | 0 | 0 | 75,000 |
| “ 18...... | 58,436,500 | 0 | 3,600,000 | 0 | 0 | 0 |
| “ 25...... | 130,532,250 | 0 | 25,200,000 | 3,600,000 | 0 | 31,250 |
| Nov. 1...... | 54,477,175 | 2,000 | 14,400,000 | 3,600,000 | 0 | 406,125 |
| “ 8...... | 72,584,120 | 6,000 | 18,000,000 | 7,200,000 | 0 | 609,000 |
| “ 15...... | 132,556,500 | 0 | 18,000,000 | 5,400,000 | 0 | 1,866,500 |
| “ 22...... | 295,111,500 | 0 | 18,000,000 | 9,000,000 | 0 | 1,711,500 |
| “ 29...... | 218,309,400 | 0 | 151,200,000 | 0 | 0 | 2,254,000 |
| Dec. 6...... | 308,149,750 | 6,000 | 287,200,000 | 900,000 | 0 | 243,750 |
| “ 13...... | 864,280,915 | 3,240 | 811,000,000 | 0 | 0 | 75,625 |
| “ 20...... | 332,305,000 | 10,500 | 302,400,000 | 900,000 | 0 | 105,000 |
| “ 27...... | 239,550,800 | 800 | 225,000,000 | 0 | 0 | 20,000 |
| Average...... | 396,192,727 | 28,860,160 | 243,659,615 | 2,471,923 | 311,593 | 5,234,484 |

## TABLE I—*continued*.

### Organisms per Cubic Meter in Plankton of Illinois River in 1898.

(An asterisk at head of column indicates that all entries in it are based on filter-paper collections.)

| 1898 | *Melosira granulata* var. *spinosa* | *Melosira granulata* var. *spinosa** | *Melosira varians* | *Navicula* spp.* | *Surirella spiralis* | *Synedra acus* |
|---|---|---|---|---|---|---|
| Jan. 11...... | 0 | 0 | 0 | 0 | 0 | 14,400 |
| " 21...... | 1,000 | 24,000,000 | 2,200 | 3,000,000 | 900 | 800 |
| " 25...... | 9,090 | 0 | 49,536 | 0 | 3,870 | 42,183 |
| Feb. 3...... | 2,204 | 0 | 3,180 | 5,400,000 | 300 | 5,400 |
| " 8...... | 3,200 | 120,000 | 6,000 | 3,600,000 | 880 | 1,200 |
| " 15...... | 2,800 | 14,400,000 | 48,000 | 0 | 4,000 | 400 |
| " 22...... | 0 | 0 | 120,042 | 0 | 6,318 | 3,159 |
| Mar. 1...... | 0 | 7,200,000 | 0 | 90,000 | 400 | 400 |
| " 8...... | 0 | 3,600,000 | 0 | 1,800,000 | 800 | 400 |
| " 15...... | 8,640 | 8,100,000 | 5,200 | 900,000 | 800 | 2,800 |
| " 22...... | 60,800 | 10,800,000 | 800 | 1,800,000 | 0 | 14,000 |
| " 29...... | 30,240 | 2,700,000 | 1,000 | 900,000 | 400 | 8,600 |
| Apr. 5...... | 1,620 | 900,000 | 1,800 | 4,500,000 | 0 | 1,400 |
| " 12...... | 3,960 | 1,620,000 | 0 | 4,500,000 | 300 | 2,100 |
| " 19...... | 2,800 | 7,200,000 | 3,600 | 3,600,000 | 800 | 6,800 |
| " 26...... | 595,840 | 0 | 72,960 | 1,800,000 | 800 | 614,400 |
| May 3...... | 230,400 | 9,000,000 | 552,960 | 6,000,000 | 6,200 | 2,016,000 |
| " 10...... | 3,421,440 | 0 | 3,164,160 | 21,600,000 | 1,600 | 9,043,200 |
| " 17...... | 259,200 | 0 | 1,241,200 | 64,800,000 | 0 | 3,801,600 |
| " 24...... | 109,040 | 10,800,000 | 126,720 | 9,000,000 | 200 | 86,400 |
| " 31...... | 293,360 | 1,008,000 | 101,760 | 5,400,000 | 40 | 14,400 |
| June 7...... | 26,028,800 | 103,320,000 | 998,400 | 1,800,000 | 0 | 28,800 |
| " 14...... | 0 | 128,560,000 | 488,320 | 3,600,000 | 800 | 57,600 |
| " 21...... | 32,114,880 | 232,200,000 | 470,400 | 14,400,000 | 1,600 | 127,200 |
| " 28...... | 153,120 | 44,100,000 | 72,960 | 2,700,000 | 800 | 20,800 |
| July 5...... | 3,628,800 | 70,200,000 | 34,560 | 7,200,000 | 1,600 | 3,200 |
| " 12...... | 1,811,520 | 41,040,000 | 86,400 | 2,700,000 | 1,600 | 3,600 |
| " 19...... | 947,520 | 115,200,000 | 5,600 | 54,000,000 | 1,600 | 1,600 |
| " 26...... | 133,920 | 20,200,000 | 1,000 | 3,600,000 | 800 | 400 |
| Aug. 2...... | 316,240 | 50,400,000 | 12,800 | 12,600,000 | 6,400 | 4,000 |
| " 9...... | 1,484,000 | 27,720,000 | 800 | 10,800,000 | 2,000 | 800 |
| " 16...... | 1,250,656 | 0 | 6,400 | 7,200,000 | 1,600 | 800 |
| " 23...... | 366,400 | 50,475,000 | 12,800 | 7,200,000 | 3,200 | 2,400 |
| " 30...... | 5,028,800 | 104,490,000 | 0 | 3,600,000 | 0 | 6,400 |
| Sept. 6...... | 1,122,000 | 56,250,000 | 0 | 5,400,000 | 0 | 800 |
| " 13...... | 1,200,000 | 64,800,000 | 7,000 | 16,200,000 | 500 | 1,500 |
| " 20...... | 2,227,000 | 33,480,000 | 30,000 | 1,800,000 | 500 | 5,000 |
| " 27...... | 5,499,840 | 146,520,000 | 94,080 | 9,000,000 | 4,800 | 17,600 |
| Oct. 4...... | 805,800 | 40,500,000 | 18,900 | 9,900,000 | 0 | 2,000 |
| " 11...... | 840,000 | 37,800,000 | 55,350 | 0 | 0 | 3,500 |
| " 18...... | 436,650 | 27,360,000 | 348,000 | 12,600,000 | 0 | 8,000 |
| " 25...... | 736,000 | 56,700,000 | 214,500 | 5,400,000 | 1,000 | 2,000 |
| Nov. 1...... | 83,200 | 3,600,000 | 70,550 | 12,600,000 | 0 | 12,500 |
| " 8...... | 98,700 | 10,800,000 | 25,120 | 19,800,000 | 0 | 19,000 |
| " 15...... | 7,000 | 22,680,000 | 57,400 | 21,600,000 | 3,000 | 6,000 |
| " 22...... | 60,000 | 194,400,000 | 0 | 23,400,000 | 0 | 4,000 |
| " 29...... | 2,000 | 13,500,000 | 9,500 | 18,000,000 | 0 | 3,500 |
| Dec. 6...... | 0 | 5,400,000 | 0 | 6,300,000 | 0 | 1,500 |
| " 13...... | 0 | 0 | 0 | 6,300,000 | 0 | 2,600 |
| " 20...... | 0 | 4,500,000 | 0 | 4,500,000 | 0 | 4,400 |
| " 27...... | 0 | 0 | 0 | 2,700,000 | 0 | 1,600 |
| Average...... | 1,181,125 | 34,762,365 | 148,626 | 8,569,038 | 1,612 | 308,330 |

## TABLE I—*continued.*

### Organisms per Cubic Meter in Plankton of Illinois River in 1898.

(An asterisk at head of column indicates that all entries in it are based on filter-paper collections.)

| 1898 | *Synedra acus** | Total *Conjugatæ* | *Closterium accrosum* | *Closterium gracile* | *Closterium lunula* | *Staurastrum gracile* | Total *Protozoa* |
|---|---|---|---|---|---|---|---|
| Jan. 11...... | 40,000 | 0 | 0 | 0 | 0 | 0 | 123,518,320 |
| " 21...... | 0 | 80 | 0 | 0 | 80 | 0 | 36,316,000 |
| " 25...... | 0 | 0 | 0 | 0 | 0 | 0 | 43,464,482 |
| Feb. 3...... | 0 | 100 | 0 | 0 | 100 | 0 | 21,691,300 |
| " 8...... | 60,000 | 80 | 0 | 0 | 80 | 0 | 6,096,160 |
| " 15...... | 3,600,000 | 400 | 0 | 0 | 400 | 0 | 19,093,280 |
| " 22...... | 0 | 0 | 0 | 0 | 0 | 0 | 44,060,478 |
| Mar. 1...... | 900,000 | 0 | 0 | 0 | 0 | 0 | 11,727,360 |
| " 8...... | 3,600,000 | 40 | 0 | 0 | 40 | 0 | 2,516,240 |
| " 15...... | 2,480,000 | 1,000 | 400 | 0 | 600 | 200 | 22,368,600 |
| " 22...... | 13,620,000 | 600 | 200 | 0 | 400 | 0 | 29,817,200 |
| " 29...... | 4,200,000 | 1,000 | 0 | 400 | 600 | 0 | 7,169,620 |
| Apr. 5...... | 2,340,000 | 440 | 40 | 100 | 200 | 0 | 15,052,540 |
| " 12...... | 4,500,000 | 300 | 200 | 100 | 0 | 0 | 29,011,320 |
| " 19...... | 23,580,000 | 1,200 | 0 | 800 | 400 | 0 | 39,856,000 |
| " 26...... | 82,800,000 | 3,200 | 0 | 0 | 3,200 | 0 | 94,337,920 |
| May 3...... | 240,000,000 | 3,200 | 3,200 | 0 | 0 | 0 | 1,081,381,200 |
| " 10...... | 813,600,000 | 1,800,000 | 0 | 0 | 0 | 0 | 222,233,400 |
| " 17...... | 367,200,000 | 3,000 | 800 | 1,600 | 800 | 0 | 252,834,800 |
| " 24...... | 1,800,000 | 7,200 | 1,000 | 200 | 6,000 | 0 | 121,175,320 |
| " 31...... | 37,800,000 | 62,200 | 400 | 0 | 1,800 | 0 | 31,584,920 |
| June 7...... | 17,100,000 | 1,200 | 800 | 0 | 400 | 0 | 27,679,000 |
| " 14...... | 21,600,000 | 2,000 | 200 | 0 | 1,800 | 0 | 49,614,800 |
| " 21...... | 79,200,000 | 1,100 | 800 | 0 | 300 | 0 | 230,167,200 |
| " 28...... | 5,400,000 | 800 | 0 | 0 | 0 | 0 | 191,626,440 |
| July 5...... | 1,800,000 | 800 | 0 | 0 | 0 | 400 | 78,477,400 |
| " 12...... | 5,400,000 | 0 | 0 | 0 | 0 | 0 | 49,852,520 |
| " 19...... | 39,600,000 | 1,200 | 400 | 800 | 0 | 0 | 295,478,560 |
| " 26...... | 900,000 | 60 | 60 | 0 | 0 | 0 | 121,362,600 |
| Aug. 2...... | 0 | 40 | 40 | 0 | 0 | 0 | 112,224,400 |
| " 9...... | 0 | 80 | 80 | 0 | 0 | 0 | 566,013,480 |
| " 16...... | 5,400,000 | 120 | 60 | 0 | 60 | 0 | 166,746,460 |
| " 23...... | 0 | 0 | 0 | 0 | 0 | 0 | 129,617,660 |
| " 30...... | 6,300,000 | 240,200 | 120 | 0 | 80 | 0 | 95,553,600 |
| Sept. 6...... | 3,600,000 | 2,400 | 2,400 | 0 | 0 | 0 | 137,009,680 |
| " 13...... | 7,200,000 | 1,060 | 500 | 500 | 60 | 0 | 50,995,120 |
| " 20...... | 16,200,000 | 120,620 | 500 | 2,500 | 120 | 0 | 65,106,000 |
| " 27...... | 1,800,000 | 6,800 | 200 | 6,400 | 200 | 0 | 46,830,100 |
| Oct. 4...... | 42,300,000 | 241,000 | 0 | 1,000 | 500 | 500 | 49,825,580 |
| " 11...... | 1,800,000 | 1,160 | 80 | 1,000 | 80 | 0 | 15,982,080 |
| " 18...... | 13,500,000 | 160 | 80 | 0 | 80 | 0 | 19,122,540 |
| " 25...... | 27,000,000 | 500 | 500 | 0 | 0 | 0 | 6,776,060 |
| Nov. 1...... | 5,400,000 | 9,500 | 2,500 | 500 | 6,500 | 500 | 26,343,120 |
| " 8...... | 16,200,000 | 2,000 | 1,000 | 0 | 1,000 | 0 | 15,566,060 |
| " 15...... | 37,800,000 | 1,100 | 1,000 | 0 | 1,000 | 0 | 36,542,100 |
| " 22...... | 23,400,000 | 200 | 0 | 0 | 2,000 | 0 | 24,435,040 |
| " 29...... | 30,600,000 | 0 | 500 | 0 | 20 | 0 | 74,444,400 |
| Dec. 6...... | 8,100,000 | 520 | 0 | 0 | 0 | 0 | 57,242,080 |
| " 13...... | 27,000,000 | 0 | 0 | 0 | 0 | 0 | 149,284,900 |
| " 20...... | 5,400,000 | 0 | 0 | 0 | 0 | 0 | 116,833,160 |
| " 27...... | 10,800,000 | 200 | 200 | 0 | 0 | 0 | 68,456,620 |
| Average...... | 39,639,231 | 48,456 | 348 | 305 | 556 | 31 | 102,220,941 |

TABLE I—*continued.*

ORGANISMS PER CUBIC METER IN PLANKTON OF ILLINOIS RIVER IN 1898.

(An asterisk at head of column indicates that all entries in it are based on filter-paper collections.)

| 1898 | Total Mastigophora | *Bicosœca lacustris* | *Chilomonas paramæcium* | *Dinobryon sertularia* | *Dinobryon sertularia* var. *angulatum* | *Dinobryon sertularia* var. *divergens* |
|---|---|---|---|---|---|---|
| Jan. 11...... | 122,484,100 | 0 | 0 | 0 | 0 | 0 |
| " 21...... | 36,086,000 | 0 | 0 | 0 | 0 | 0 |
| " 25...... | 43,208,127 | 0 | 0 | 0 | 0 | 0 |
| Feb. 3...... | 20,321,700 | 0 | 0 | 0 | 0 | 0 |
| " 8...... | 5,461,600 | 0 | 0 | 0 | 0 | 0 |
| " 15...... | 18,039,600 | 0 | 0 | 0 | 0 | 0 |
| " 22...... | 43,400,000 | 0 | 0 | 0 | 0 | 0 |
| Mar. 1...... | 9,940,000 | 0 | 0 | 0 | 0 | 0 |
| " 8...... | 2,009,200 | 0 | 0 | 0 | 0 | 0 |
| " 15...... | 22,035,600 | 0 | 0 | 0 | 0 | 0 |
| " 22...... | 29,539,000 | 0 | 0 | 17,800 | 0 | 0 |
| " 29...... | 6,864,800 | 0 | 0 | 0 | 0 | 0 |
| Apr. 5...... | 14,809,800 | 0 | 0 | 0 | 0 | 0 |
| " 12...... | 27,662,900 | 0 | 0 | 0 | 0 | 0 |
| " 19...... | 38,507,900 | 0 | 60,000 | 8,000 | 35,040 | 8,000 |
| " 26...... | 86,614,400 | 0 | 10,800,000 | 1,806,400 | 598,400 | 1,555,200 |
| May 3...... | 1,063,924,800 | 0 | 7,200,000 | 2,764,800 | 0 | 2,104,100 |
| " 10...... | 203,922,800 | 0 | 1,800,000 | 16,153,600 | 4,432,000 | 39,648,000 |
| " 17...... | 231,154,200 | 0 | 0 | 43,200 | 0 | 1,584,000 |
| " 24...... | 120,175,000 | 0 | 1,800,000 | 3,600 | 0 | 18,000 |
| " 31...... | 29,293,200 | 0 | 0 | 0 | 0 | 0 |
| June 7...... | 19,855,400 | 460,800 | 0 | 0 | 14,400 | 56,000 |
| " 14...... | 43,112,400 | 3,801,600 | 0 | 0 | 0 | 16,000 |
| " 21...... | 218,131,200 | 432,000 | 0 | 3,200 | 12,000 | 0 |
| " 28...... | 185,098,240 | 86,400 | 0 | 0 | 172,800 | 47,040 |
| July 5...... | 42,053,200 | 72,000 | 0 | 0 | 0 | 0 |
| " 12...... | 45,923,600 | 14,400 | 0 | 0 | 0 | 0 |
| " 19...... | 294,724,520 | 0 | 0 | 0 | 0 | 0 |
| " 26...... | 120,850,000 | 0 | 0 | 0 | 0 | 0 |
| Aug. 2...... | 107,710,800 | 0 | 0 | 0 | 0 | 0 |
| " 9...... | 496,927,200 | 0 | 0 | 0 | 0 | 0 |
| " 16...... | 166,452,800 | 0 | 0 | 0 | 0 | 0 |
| " 23...... | 128,830,460 | 0 | 0 | 0 | 0 | 0 |
| " 30...... | 95,423,200 | 0 | 0 | 0 | 0 | 0 |
| Sept. 6...... | 76,982,440 | 0 | 0 | 0 | 0 | 0 |
| " 13...... | 49,515,000 | 7,500 | 0 | 0 | 0 | 0 |
| " 20...... | 63,144,000 | 0 | 0 | 0 | 0 | 0 |
| " 27...... | 45,854,000 | 218,400 | 0 | 0 | 0 | 0 |
| Oct. 4...... | 48,193,000 | 251,000 | 1,800,000 | 0 | 0 | 0 |
| " 11...... | 15,129,540 | 486,000 | 0 | 0 | 0 | 0 |
| " 18...... | 17,367,000 | 25,000 | 0 | 0 | 0 | 0 |
| " 25...... | 5,416,500 | 13,500 | 0 | 0 | 0 | 0 |
| Nov. 1...... | 25,325,500 | 2,000 | 0 | 0 | 0 | 0 |
| " 8...... | 14,564,000 | 0 | 3,600,000 | 25,000 | 0 | 0 |
| " 15...... | 36,011,000 | 0 | 0 | 0 | 0 | 0 |
| " 22...... | 23,494,000 | 0 | 0 | 0 | 0 | 0 |
| " 29...... | 73,719,000 | 0 | 0 | 38,500 | 0 | 0 |
| Dec. 6...... | 56,400,500 | 0 | 0 | 0 | 0 | 0 |
| " 13...... | 148,740,000 | 0 | 1,800,000 | 0 | 0 | 0 |
| " 20...... | 116,344,800 | 0 | 0 | 247,200 | 6,000 | 0 |
| " 27...... | 67,965,800 | 0 | 0 | 69,600 | 0 | 0 |
| Average...... | 95,852,602 | 112,896 | 555,000 | 407,602 | 101,358 | 866,083 |

TABLE I—*continued.*

ORGANISMS PER CUBIC METER IN PLANKTON OF ILLINOIS RIVER IN 1898.

(An asterisk at head of column indicates that all entries in it are based on filter-paper collections.)

| 1898 | *Dinobryon sertularia* var. *stipitatum* | *Eudorina elegans* | *Euglena acus* | *Euglena acus** | *Euglena oxyuris* | *Euglena oxyuris** |
|---|---|---|---|---|---|---|
| Jan. 11...... | 0 | 0 | 0 | 0 | 0 | 0 |
| " 21...... | 0 | 0 | 0 | 0 | 100 | 0 |
| " 25...... | 0 | 0 | 0 | 0 | 0 | 0 |
| Feb. 3...... | 0 | 0 | 0 | 0 | 0 | 0 |
| " 8...... | 0 | 0 | 0 | 0 | 0 | 0 |
| " 15...... | 0 | 0 | 0 | 0 | 0 | 0 |
| " 22...... | 0 | 0 | 0 | 0 | 0 | 0 |
| Mar. 1...... | 0 | 0 | 0 | 0 | 0 | 0 |
| " 8...... | 0 | 0 | 0 | 0 | 0 | 0 |
| " 15...... | 0 | 3,600 | 0 | 40,000 | 0 | 40,000 |
| " 22...... | 0 | 800 | 0 | 0 | 0 | 0 |
| " 29...... | 0 | 2,600 | 0 | 0 | 0 | 0 |
| Apr. 5...... | 0 | 2,800 | 0 | 0 | 0 | 0 |
| " 12...... | 0 | 1,800 | 100 | 0 | 0 | 0 |
| " 19...... | 9,960 | 36,000 | 0 | 0 | 100 | 0 |
| " 26...... | 1,830,400 | 240,000 | 800 | 0 | 0 | 0 |
| May 3...... | 4,883,200 | 240,000 | 0 | 0 | 3,200 | 0 |
| " 10...... | 24,608,000 | 48,800 | 0 | 0 | 0 | 0 |
| " 17...... | 28,800 | 32,800 | 0 | 90,000 | 0 | 180,000 |
| " 24...... | 0 | 1,000 | 0 | 0 | 0 | 0 |
| " 31...... | 0 | 400 | 0 | 0 | 0 | 0 |
| June 7...... | 0 | 9,600 | 0 | 0 | 0 | 0 |
| " 14...... | 0 | 60,000 | 0 | 900,000 | 1,600 | 0 |
| " 21...... | 0 | 30,400 | 0 | 0 | 2,400 | 0 |
| " 28...... | 0 | 4,000 | 0 | 0 | 0 | 1,800,000 |
| July 5...... | 0 | 400 | 400 | 0 | 800 | 0 |
| " 12...... | 0 | 800 | 400 | 0 | 1,200 | 0 |
| " 19...... | 0 | 7,600 | 0 | 0 | 400 | 3,600,000 |
| " 26...... | 0 | 4,000 | 0 | 0 | 2,400 | 3,600,000 |
| Aug. 2...... | 0 | 8,000 | 800 | 120,000 | 3,200 | 1,800,000 |
| " 9...... | 0 | 400 | 800 | 0 | 1,200 | 3,600,000 |
| " 16...... | 0 | 800 | 800 | 120,000 | 0 | 3,600,000 |
| " 23...... | 0 | 3,200 | 1,600 | 0 | 6,400 | 120,000 |
| " 30...... | 0 | 2,400 | 800 | 0 | 3,200 | 4,500,000 |
| Sept. 6...... | 0 | 40 | 1,600 | 900,000 | 10,400 | 5,400,000 |
| " 13...... | 0 | 500 | 0 | 0 | 1,500 | 3,600,000 |
| " 20...... | 0 | 2,000 | 1,500 | 0 | 1,000 | 1,800,000 |
| " 27...... | 0 | 1,600 | 6,400 | 1,800,000 | 9,600 | 9,000,000 |
| Oct. 4...... | 0 | 0 | 1,500 | 3,600,000 | 1,000 | 2,700,000 |
| " 11...... | 0 | 0 | 1,000 | 1,800,000 | 500 | 1,800,000 |
| " 18...... | 0 | 0 | 0 | 0 | 0 | 900,000 |
| " 25...... | 0 | 0 | 0 | 0 | 0 | 0 |
| Nov. 1...... | 0 | 0 | 0 | 0 | 0 | 0 |
| " 8...... | 0 | 0 | 0 | 1,800,000 | 0 | 0 |
| " 15...... | 0 | 0 | 1,000 | 0 | 0 | 1,800,000 |
| " 22...... | 0 | 0 | 0 | 0 | 0 | 0 |
| " 29...... | 0 | 0 | 0 | 0 | 0 | 120,000 |
| Dec. 6...... | 0 | 0 | 0 | 0 | 0 | 0 |
| " 13...... | 0 | 500 | 0 | 0 | 0 | 0 |
| " 20...... | 22,000 | 0 | 0 | 0 | 0 | 0 |
| " 27...... | 0 | 0 | 0 | 0 | 0 | 0 |
| Average...... | 603,911 | 14,362 | 375 | 214,807 | 963 | 960,769 |

# TABLE I—*continued.*

## Organisms per Cubic Meter in Plankton of Illinois River in 1898.

(An asterisk at head of column indicates that all entries in it are based on filter-paper collections.)

| 1898 | *Euglena viridis* | *Euglena viridis** | *Glenodinium cinctum* | *Glenodinium cinctum** | *Gonium pectorale* | *Lepocinclis ovum* | *Lepocinclis ovum** |
|---|---|---|---|---|---|---|---|
| Jan. 11...... | 0 | 0 | 0 | 80,000 | 0 | 0 | 0 |
| " 21...... | 0 | 0 | 0 | 0 | 0 | 100 | 0 |
| " 25...... | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Feb. 3...... | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| " 8...... | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| " 15...... | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| " 22...... | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Mar. 1...... | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| " 8...... | 0 | 0 | 400 | 200,000 | 0 | 0 | 0 |
| " 15...... | 200 | 0 | 200 | 240,000 | 0 | 0 | 0 |
| " 22...... | 400 | 0 | 0 | 4,260,000 | 0 | 0 | 0 |
| " 29...... | 0 | 0 | 0 | 240,000 | 0 | 0 | e |
| Apr. 5...... | 0 | 0 | 0 | 240,000 | 0 | 200 | 0 |
| " 12...... | 0 | 0 | 0 | 120,000 | 0 | 200 | 0 |
| " 19...... | 400 | 0 | 1,200 | 240,000 | 0 | 800 | 0 |
| " 26...... | 3,200 | 360,000 | 0 | 0 | 0 | 0 | 0 |
| May 3...... | 0 | 120,000 | 0 | 0 | 22,400 | 0 | 0 |
| " 10...... | 0 | 120,000 | 0 | 0 | 200 | 0 | 0 |
| " 17...... | 0 | 3,600,000 | 0 | 90,000 | 800 | 0 | 0 |
| " 24...... | 0 | 630,000 | 0 | 0 | 0 | 200 | 1,800,000 |
| " 31...... | 0 | 60,000 | 0 | 0 | 0 | 400 | 0 |
| June 7...... | 0 | 0 | 0 | 900,000 | 0 | 0 | 180,000 |
| " 14...... | 1,600 | 2,700,000 | 0 | 60,000 | 0 | 800 | 420,000 |
| " 21...... | 3,200 | 7,200,000 | 0 | 7,200,000 | 0 | 2,400 | 240,000 |
| " 28...... | 0 | 900,000 | 0 | 0 | 0 | 5,600 | 0 |
| July 5...... | 0 | 120,000 | 0 | 0 | 0 | 1,600 | 0 |
| " 12...... | 0 | 2,700,000 | 0 | 0 | 0 | 800 | 0 |
| " 19...... | 2,400 | 3,600,000 | 0 | 7,200,000 | 0 | 4,400 | 3,600,000 |
| " 26...... | 3,200 | 14,400,000 | 0 | 2,700,000 | 0 | 30,000 | 900,000 |
| Aug. 2...... | 1,600 | 7,200,000 | 20,000 | 12,600,000 | 0 | 50,400 | 360,000 |
| " 9...... | 4,800 | 7,200,000 | 400 | 25,200,000 | 0 | 6,400 | 3,600,000 |
| " 16...... | 0 | 5,400,000 | 0 | 5,400,000 | 0 | 800 | 720,000 |
| " 23...... | 4,800 | 4,500,000 | 0 | 0 | 0 | 14,400 | 3,600,000 |
| " 30...... | 8,000 | 2,700,000 | 800 | 900,000 | 800 | 43,200 | 900,000 |
| Sept. 6...... | 800 | 3,600,000 | 0 | 900,000 | 0 | 11,200 | 240,000 |
| " 13...... | 1,000 | 1,800,000 | 0 | 0 | 0 | 1,000 | 0 |
| " 20...... | 3,000 | 0 | 500 | 120,000 | 0 | 5,000 | 1,800,000 |
| " 27...... | 6,400 | 1,800,000 | 0 | 0 | 3,200 | 8,000 | 480,000 |
| Oct. 4...... | 0 | 6,300,000 | 0 | 0 | 0 | 2,500 | 1,800,000 |
| " 11...... | 0 | 120,000 | 0 | 0 | 0 | 2,000 | 0 |
| " 18...... | 0 | 0 | 0 | 0 | 0 | 500 | 120,000 |
| " 25...... | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Nov. 1...... | 0 | 0 | 0 | 0 | 0 | 500 | 0 |
| " 8...... | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| " 15...... | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| " 22...... | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| " 29...... | 0 | 0 | 0 | 0 | 0 | 0 | 120,000 |
| Dec. 6...... | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| " 13...... | 0 | 1,020,000 | 0 | 60,000 | 0 | 0 | 0 |
| " 20...... | 0 | 0 | 0 | 900,000 | 0 | 0 | 0 |
| " 27...... | 0 | 0 | 0 | 960,000 | 0 | 0 | 0 |
| Average...... | 8,653 | 1,571,731 | 452 | 1,360,192 | 526 | 3,719 | 401,538 |

## TABLE I—*continued*.

### ORGANISMS PER CUBIC METER IN PLANKTON OF ILLINOIS RIVER IN 1898.

(An asterisk at head of column indicates that all entries in it are based on filter-paper collections.)

| 1898 | *Mallomonas producta* | *Pandorina morum* | *Peridinium tabulatum* | *Peridinium tabulatum** | *Phacus longicauda* | *Phacus pleuronectes* | *Platydorina caudata* | *Pleodorina californica* |
|---|---|---|---|---|---|---|---|---|
| Jan. 11 | 0 | 0 | 400 | 0 | 0 | 0 | 0 | 0 |
| " 21 | 0 | 0 | 100 | 0 | 100 | 0 | 0 | 0 |
| " 25 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Feb. 3 | 0 | 0 | 0 | 0 | 0 | 0 | 100 | 0 |
| " 8 | 0 | 0 | 400 | 0 | 0 | 0 | 0 | 0 |
| " 15 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| " 22 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Mar. 1 | 0 | 0 | 400 | 0 | 0 | 0 | 0 | 0 |
| " 8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| " 15 | 0 | 0 | 600 | 0 | 0 | 0 | 0 | 0 |
| " 22 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| " 29 | 0 | 0 | 200 | 0 | 600 | 0 | 0 | 0 |
| Apr. 5 | 0 | 0 | 200 | 0 | 0 | 0 | 0 | 0 |
| " 12 | 0 | 0 | 500 | 0 | 600 | 0 | 0 | 0 |
| " 19 | 0 | 800 | 400 | 0 | 1,600 | 0 | 0 | 0 |
| " 26 | 0 | 48,000 | 0 | 0 | 3,200 | 0 | 0 | 0 |
| May 3 | 12,800 | 48,400 | 0 | 0 | 3,200 | 0 | 0 | 0 |
| " 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| " 17 | 0 | 800 | 0 | 0 | 0 | 0 | 0 | 0 |
| " 24 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| " 31 | 0 | 0 | 0 | 0 | 400 | 0 | 0 | 0 |
| June 7 | 835,200 | 8,000 | 0 | 120,000 | 200 | 0 | 0 | 0 |
| " 14 | 28,800 | 60,000 | 0 | 900,000 | 8,800 | 800 | 0 | 0 |
| " 21 | 28,800 | 40,800 | 2,400 | 1,200,000 | 8,800 | 0 | 0 | 0 |
| " 28 | 28,800 | 9,600 | 8,800 | 79,200,000 | 4,800 | 800 | 0 | 0 |
| July 5 | 0 | 400 | 2,000 | 5,400,000 | 4,800 | 0 | 0 | 0 |
| " 12 | 0 | 800 | 18,800 | 10,800,000 | 3,200 | 400 | 400 | 0 |
| " 19 | 0 | 12,000 | 49,600 | 86,400,000 | 3,200 | 400 | 400 | 120 |
| " 26 | 0 | 63,200 | 66,800 | 15,300,000 | 6,800 | 800 | 0 | 400 |
| Aug. 2 | 800 | 59,200 | 12,000 | 120,000 | 11,200 | 2,000 | 0 | 0 |
| " 9 | 0 | 1,200 | 7,200 | 120,000 | 4,800 | 0 | 0 | 0 |
| " 16 | 0 | 0 | 3,200 | 0 | 8,000 | 0 | 0 | 0 |
| " 23 | 0 | 2,400 | 6,400 | 1,800,000 | 4,800 | 800 | 0 | 60 |
| " 30 | 0 | 3,200 | 6,400 | 0 | 8,000 | 1,600 | 0 | 0 |
| Sept. 6 | 0 | 2,400 | 0 | 0 | 12,800 | 1,600 | 0 | 0 |
| " 13 | 3,000 | 0 | 0 | 0 | 3,000 | 1,000 | 0 | 0 |
| " 20 | 0 | 0 | 1,500 | 0 | 7,000 | 500 | 0 | 0 |
| " 27 | 1,600 | 100 | 4,800 | 0 | 35,200 | 4,800 | 0 | 0 |
| Oct. 4 | 0 | 0 | 0 | 0 | 7,000 | 0 | 0 | 0 |
| " 11 | 0 | 0 | 0 | 0 | 1,500 | 0 | 0 | 0 |
| " 18 | 0 | 500 | 0 | 0 | 1,000 | 0 | 0 | 0 |
| " 25 | 0 | 0 | 0 | 0 | 500 | 0 | 0 | 0 |
| Nov. 1 | 0 | 0 | 0 | 0 | 500 | 0 | 0 | 0 |
| " 8 | 0 | 0 | 0 | 0 | 1,000 | 0 | 0 | 0 |
| " 15 | 0 | 0 | 0 | 0 | 1,000 | 0 | 0 | 0 |
| " 22 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| " 29 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Dec. 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| " 13 | 0 | 0 | 0 | 180,000 | 0 | 0 | 0 | 0 |
| " 20 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| " 27 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Average | 17,520 | 6,957 | 3,711 | 3,875,769 | 3,031 | 298 | 17 | 11 |

TABLE I—*continued.*

ORGANISMS PER CUBIC METER IN PLANKTON OF ILLINOIS RIVER IN 1898.

(An asterisk at head of column indicates that all entries in it are based on filter-paper collections.)

| 1898 | *Syncrypta volvox* | *Synura uvella* | *Synura uvella** | *Trachelomonas acuminata* | *Trachelomonas acuminata** | *Trachelomonas hispida* | *Trachelomonas volvocina** |
|---|---|---|---|---|---|---|---|
| Jan. 11...... | 0 | 100 | 0 | 0 | 0 | 3,600 | 0 |
| " 21...... | 0 | 5,600 | 0 | 0 | 0 | 3,800 | 0 |
| " 25...... | 0 | 7,740 | 0 | 0 | 0 | 387 | 0 |
| Feb. 3...... | 0 | 1,600 | 0 | 0 | 0 | 4,600 | 480,000 |
| " 8...... | 0 | 800 | 0 | 0 | 0 | 800 | 60,000 |
| " 15...... | 0 | 10,800 | 0 | 0 | 3,600,000 | 28,800 | 0 |
| " 22...... | 0 | 0 | 0 | 0 | 0 | 0 | 200,000 |
| Mar. 1...... | 800 | 8,800 | 0 | 0 | 0 | 800 | 900,000 |
| " 8...... | 400 | 8,800 | 0 | 0 | 0 | 800 | 900,000 |
| " 15...... | 1,200 | 109,200 | 0 | 0 | 0 | 0 | 1,800,000 |
| " 22...... | 0 | 221,600 | 60,000 | 0 | 0 | 0 | 10,800,000 |
| " 29...... | 0 | 320,600 | 0 | 0 | 0 | 200 | 900,000 |
| Apr. 5...... | 0 | 166,600 | 0 | 200 | 0 | 0 | 1,800,000 |
| " 12...... | 100 | 17,800 | 0 | 0 | 0 | 0 | 0 |
| " 19...... | 0 | 126,000 | 60,000 | 0 | 0 | 0 | 9,000,000 |
| " 26...... | 0 | 121,600 | 120,000 | 0 | 0 | 0 | 4,500,000 |
| May 3...... | 0 | 102,400 | 0 | 0 | 0 | 3,200 | 3,600,000 |
| " 10...... | 0 | 38,400 | 0 | 0 | 0 | 0 | 9,000,000 |
| " 17...... | 0 | 21,600 | 0 | 0 | 3,600,000 | 0 | 14,400,000 |
| " 24...... | 0 | 1,400 | 0 | 0 | 0 | 200 | 360,000 |
| " 31...... | 0 | 200 | 0 | 0 | 60,000 | 0 | 180,000 |
| June 7...... | 0 | 0 | 0 | 0 | 0 | 0 | 4,500,000 |
| " 14...... | 0 | 0 | 0 | 0 | 120,000 | 0 | 7,200,000 |
| " 21...... | 0 | 1,600 | 0 | 800 | 7,200,000 | 0 | 147,600,000 |
| " 28...... | 0 | 800 | 0 | 0 | 6,300,000 | 0 | 38,700,000 |
| July 5...... | 0 | 0 | 0 | 400 | 1,800,000 | 0 | 1,800,000 |
| " 12...... | 0 | 1,200 | 0 | 800 | 900,000 | 0 | 10,800,000 |
| " 19...... | 0 | 0 | 0 | 800 | 3,600,000 | 0 | 86,400,000 |
| " 26...... | 0 | 0 | 0 | 2,000 | 3,600,000 | 9,200 | 42,300,000 |
| Aug. 2...... | 0 | 0 | 0 | 12,800 | 600,000 | 800 | 18,000,000 |
| " 9...... | 0 | 0 | 0 | 800 | 3,600,000 | 0 | 252,000,000 |
| " 16...... | 0 | 0 | 0 | 4,000 | 3,600,000 | 1,600 | 93,600,000 |
| " 23...... | 0 | 0 | 0 | 3,200 | 1,800,000 | 800 | 65,700,000 |
| " 30...... | 0 | 0 | 0 | 8,800 | 1,800,000 | 1,600 | 18,000,000 |
| Sept. 6...... | 0 | 0 | 0 | 4,000 | 5,400,000 | 800 | 16,200,000 |
| " 13...... | 0 | 0 | 0 | 0 | 0 | 1,000 | 6,300,000 |
| " 20...... | 0 | 4,000 | 0 | 1,500 | 0 | 0 | 1,800,000 |
| " 27...... | 0 | 1,600 | 0 | 4,800 | 3,600,000 | 1,600 | 9,000,000 |
| Oct. 4...... | 0 | 0 | 0 | 500 | 1,800,000 | 0 | 11,700,000 |
| " 11...... | 0 | 0 | 0 | 0 | 120,000 | 0 | 1,800,000 |
| " 18...... | 0 | 0 | 0 | 0 | 900,000 | 0 | 2,700,000 |
| " 25...... | 0 | 500 | 0 | 0 | 0 | 0 | 5,400,000 |
| Nov. 1...... | 0 | 2,000 | 0 | 0 | 120,000 | 0 | 1,800,000 |
| " 8...... | 1,000 | 16,000 | 0 | 0 | 0 | 0 | 1,800,000 |
| " 15...... | 0 | 9,000 | 0 | 0 | 0 | 0 | 0 |
| " 22...... | 0 | 94,000 | 0 | 0 | 1,800,000 | 0 | 5,400,000 |
| " 29...... | 4,500 | 1,999,500 | 1,320,000 | 0 | 0 | 0 | 3,600,000 |
| Dec. 6...... | 13,500 | 1,693,500 | 2,280,000 | 0 | 0 | 0 | 900,000 |
| " 13...... | 2,000 | 78,000 | 2,760,000 | 0 | 0 | 500 | 2,400,000 |
| " 20...... | 6,200 | 2,764,800 | 900,000 | 0 | 0 | 0 | 0 |
| " 27...... | 800 | 395,200 | 300,000 | 0 | 0 | 0 | 2,700,000 |
| Average...... | 625 | 179,138 | 150,000 | 873 | 1,094,615 | 1,251 | 17,672,692 |

## TABLE I—*continued.*

### Organisms per Cubic Meter in Plankton of Illinois River in 1898.

(An asterisk at head of column indicates that all entries in it are based on filter-paper collections.)

| 1898 | Total Rhizopoda | *Arcella discoides* | *Arcella vulgaris* | *Centropyxis aculeata* | *Centropyxis aculeata* var. *ecornis* | *Cochliopodium bilimbosum* | *Cyphoderia margaritacea* | *Difflugia acuminata* |
|---|---|---|---|---|---|---|---|---|
| Jan. 11...... | 440,500 | 100 | 0 | 0 | 0 | 0 | 0 | 0 |
| " 21...... | 32,800 | 100 | 200 | 0 | 0 | 100 | 0 | 0 |
| " 25...... | 66,338 | 387 | 387 | 387 | 1,161 | 20,898 | 774 | 1,935 |
| Feb. 3...... | 122,900 | 0 | 0 | 0 | 0 | 1,300 | 0 | 0 |
| " 8...... | 4,880 | 0 | 0 | 0 | 0 | 3,200 | 0 | 0 |
| " 15...... | 34,880 | 800 | 0 | 800 | 800 | 0 | 0 | 80 |
| " 22...... | 141,524 | 632 | 25,272 | 12,636 | 9,477 | 3,159 | 0 | 0 |
| Mar. 1...... | 11,200 | 400 | 0 | 400 | 400 | 400 | 0 | 0 |
| " 8...... | 11,720 | 400 | 0 | 400 | 1,200 | 0 | 400 | 40 |
| " 15...... | 7,600 | 600 | 0 | 0 | 400 | 0 | 0 | 0 |
| " 22...... | 4,800 | 400 | 0 | 0 | 0 | 0 | 0 | 0 |
| " 29...... | 61,400 | 400 | 0 | 200 | 0 | 0 | 0 | 0 |
| Apr. 5...... | 700 | 100 | 100 | 100 | 0 | 0 | 0 | 0 |
| " 12...... | 3,520 | 300 | 200 | 0 | 20 | 100 | 0 | 0 |
| " 19...... | 7,300 | 400 | 0 | 0 | 0 | 400 | 400 | 0 |
| " 26...... | 6,720 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| May 3...... | 26,000 | 0 | 0 | 0 | 400 | 0 | 0 | 0 |
| " 10...... | 49,800 | 0 | 0 | 0 | 1,600 | 0 | 0 | 0 |
| " 17...... | 23,800 | 2,400 | 0 | 0 | 800 | 0 | 0 | 0 |
| " 24...... | 9,320 | 600 | 0 | 0 | 200 | 0 | 400 | 80 |
| " 31...... | 8,920 | 400 | 0 | 200 | 0 | 0 | 400 | 200 |
| June 7...... | 23,600 | 800 | 200 | 0 | 0 | 0 | 0 | 3,200 |
| " 14...... | 21,600 | 1,600 | 800 | 0 | 0 | 0 | 0 | 0 |
| " 21...... | 21,600 | 1,600 | 800 | 0 | 0 | 0 | 800 | 0 |
| " 28...... | 37,000 | 800 | 0 | 0 | 0 | 0 | 800 | 100 |
| July 5...... | 19,360 | 0 | 0 | 1,200 | 400 | 0 | 400 | 400 |
| " 12...... | 26,000 | 800 | 0 | 800 | 200 | 0 | 1,600 | 1,200 |
| " 19...... | 28,800 | 0 | 800 | 400 | 400 | 0 | 400 | 0 |
| " 26...... | 4,800 | 400 | 400 | 0 | 0 | 0 | 400 | 0 |
| Aug. 2...... | 16,800 | 800 | 4,800 | 0 | 0 | 1,600 | 0 | 0 |
| " 9...... | 7,280 | 0 | 1,600 | 0 | 400 | 1,600 | 40 | 40 |
| " 16...... | 24,060 | 0 | 2,400 | 800 | 0 | 800 | 0 | 800 |
| " 23...... | 36,800 | 800 | 5,600 | 0 | 0 | 800 | 0 | 0 |
| " 30...... | 23,200 | 800 | 5,600 | 0 | 0 | 1,600 | 0 | 0 |
| Sept. 6...... | 20,800 | 800 | 800 | 800 | 0 | 3,200 | 0 | 1,600 |
| " 13...... | 28,000 | 500 | 500 | 0 | 0 | 6,000 | 0 | 1,000 |
| " 20...... | 19,000 | 500 | 500 | 500 | 500 | 1,000 | 1,500 | 500 |
| " 27...... | 59,200 | 1,600 | 1,600 | 0 | 0 | 8,000 | 0 | 3,200 |
| Oct. 4...... | 912,580 | 0 | 40 | 0 | 40 | 500 | 500 | 0 |
| " 11...... | 9,000 | 0 | 1,000 | 0 | 0 | 0 | 0 | 0 |
| " 18...... | 10,000 | 0 | 0 | 0 | 500 | 2,000 | 1,000 | 0 |
| " 25...... | 25,060 | 1,000 | 1,500 | 1,000 | 1,000 | 500 | 500 | 500 |
| Nov. 1...... | 32,060 | 500 | 1,000 | 1,000 | 2,000 | 500 | 0 | 500 |
| " 8...... | 37,060 | 1,000 | 1,000 | 1,000 | 1,000 | 0 | 0 | 1,000 |
| " 15...... | 42,000 | 1,000 | 0 | 5,000 | 4,000 | 0 | 0 | 0 |
| " 22...... | 190,400 | 0 | 0 | 2,000 | 4,000 | 6,000 | 0 | 0 |
| " 29...... | 3,400 | 0 | 0 | 0 | 500 | 500 | 0 | 0 |
| Dec. 6...... | 121,000 | 0 | 0 | 0 | 0 | 1,000 | 0 | 0 |
| " 13...... | 600 | 0 | 0 | 0 | 0 | 600 | 0 | 0 |
| " 20...... | 1,040 | 40 | 0 | 0 | 0 | 1,000 | 0 | 0 |
| " 27...... | 220 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Average...... | 55,364 | 465 | 1,098 | 570 | 604 | 1,284 | 198 | 315 |

TABLE I—*continued*.

ORGANISMS PER CUBIC METER IN PLANKTON OF ILLINOIS RIVER IN 1898.

(An asterisk at head of column indicates that all entries in it are based on filter-paper collections.)

| 1898 | *Difflugia globulosa* | *Difflugia lobostoma* | *Difflugia pyriformis* | Total *Heliozoa* | *Nuclearia delicatula* | Total *Ciliata* | *Amphileptus* spp. | *Carchesium lachmanni* |
|---|---|---|---|---|---|---|---|---|
| Jan. 11...... | 100 | 100 | 0 | 0 | 0 | 593,420 | 0 | 26,500 |
| " 21...... | 400 | 200 | 0 | 0 | 0 | 197,100 | 0 | 37,000 |
| " 25...... | 9,675 | 7,353 | 0 | 0 | 0 | 190,017 | 13,545 | 45,666 |
| Feb. 3...... | 500 | 100 | 0 | 0 | 0 | 1,246,300 | 1,600 | 54,700 |
| " 8...... | 800 | 80 | 0 | 0 | 0 | 629,680 | 800 | 197,600 |
| " 15...... | 9,200 | 2,000 | 0 | 0 | 0 | 1,016,000 | 4,400 | 164,800 |
| " 22...... | 6,318 | 0 | 632 | 0 | 0 | 518,954 | 0 | 50,544 |
| Mar. 1...... | 4,000 | 800 | 400 | 0 | 0 | 1,773,360 | 400 | 46,400 |
| " 8...... | 2,800 | 800 | 40 | 0 | 0 | 492,920 | 800 | 54,800 |
| " 15...... | 2,600 | 1,400 | 0 | 200 | 0 | 324,200 | 200 | 89,600 |
| " 22...... | 1,600 | 800 | 0 | 2,000 | 0 | 267,800 | 400 | 22,000 |
| " 29...... | 200 | 0 | 0 | 400 | 0 | 241,420 | 400 | 10,200 |
| Apr. 5...... | 100 | 0 | 0 | 500 | 0 | 241,440 | 0 | 3,100 |
| " 12...... | 1,000 | 800 | 0 | 100 | 0 | 1,342,500 | 300 | 2,400 |
| " 19...... | 1,600 | 1,200 | 100 | 0 | 0 | 1,340,800 | 0 | 13,200 |
| " 26...... | 3,200 | 0 | 0 | 3,200 | 0 | 7,710,400 | 0 | 99,200 |
| May 3...... | 22,400 | 3,200 | 0 | 0 | 0 | 17,404,800 | 0 | 83,200 |
| " 10...... | 30,400 | 0 | 3,200 | 0 | 0 | 18,260,800 | 0 | 6,400 |
| " 17...... | 800 | 800 | 0 | 0 | 0 | 21,654,400 | 1,600 | 0 |
| " 24...... | 3,640 | 200 | 200 | 0 | 0 | 990,800 | 0 | 200 |
| " 31...... | 3,840 | 400 | 0 | 0 | 0 | 2,282,400 | 0 | 600 |
| June 7...... | 9,600 | 8,000 | 200 | 0 | 0 | 7,800,000 | 0 | 0 |
| " 14...... | 5,600 | 1,600 | 800 | 0 | 0 | 6,480,000 | 0 | 0 |
| " 21...... | 5,600 | 800 | 0 | 3,200 | 3,200 | 12,010,400 | 0 | 0 |
| " 28...... | 14,400 | 2,400 | 100 | 0 | 0 | 6,491,200 | 0 | 9,600 |
| July 5...... | 8,800 | 2,000 | 160 | 0 | 0 | 495,640 | 0 | 0 |
| " 12...... | 10,000 | 2,400 | 800 | 400 | 400 | 3,900,920 | 0 | 400 |
| " 19...... | 12,800 | 2,000 | 0 | 2,000 | 2,000 | 721,640 | 0 | 400 |
| " 26...... | 2,400 | 400 | 0 | 14,400 | 14,400 | 487,000 | 0 | 0 |
| Aug. 2...... | 5,600 | 800 | 0 | 17,600 | 17,600 | 4,474,400 | 0 | 0 |
| " 9...... | 2,800 | 400 | 0 | 78,400 | 78,400 | 69,000,200 | 0 | 0 |
| " 16...... | 8,000 | 800 | 3,200 | 13,600 | 13,600 | 253,600 | 0 | 0 |
| " 23...... | 12,800 | 0 | 2,400 | 20,800 | 20,800 | 728,000 | 0 | 1,600 |
| " 30...... | 6,400 | 800 | 800 | 7,200 | 7,200 | 122,400 | 0 | 0 |
| Sept. 6...... | 5,600 | 0 | 800 | 4,800 | 4,800 | 120,001,640 | 0 | 800 |
| " 13...... | 11,500 | 0 | 500 | 500 | 500 | 1,451,120 | 0 | 9,000 |
| " 20...... | 8,500 | 500 | 0 | 18,000 | 18,000 | 1,923,500 | 0 | 2,500 |
| " 27...... | 25,600 | 1,600 | 1,600 | 65,000 | 65,600 | 851,400 | 0 | 0 |
| Oct. 4...... | 8,000 | 500 | 500 | 0 | 0 | 720,000 | 0 | 0 |
| " 11...... | 2,500 | 1,000 | 0 | 0 | 0 | 843,540 | 0 | 3,500 |
| " 18...... | 2,000 | 1,000 | 0 | 500 | 500 | 1,744,000 | 500 | 5,000 |
| " 25...... | 15,000 | 0 | 60 | 500 | 500 | 1,334,000 | 500 | 35,000 |
| Nov. 1...... | 15,000 | 1,000 | 60 | 0 | 0 | 985,560 | 2,000 | 31,000 |
| " 8...... | 5,000 | 2,000 | 2,000 | 0 | 0 | 965,000 | 0 | 22,000 |
| " 15...... | 17,000 | 2,000 | 0 | 0 | 0 | 488,100 | 1,000 | 28,000 |
| " 22...... | 48,000 | 8,000 | 400 | 0 | 0 | 750,640 | 4,000 | 108,000 |
| " 29...... | 200 | 0 | 200 | 0 | 0 | 721,500 | 0 | 47,500 |
| Dec. 6...... | 0 | 0 | 0 | 0 | 0 | 720,580 | 40 | 7,000 |
| " 13...... | 0 | 0 | 0 | 0 | 0 | 1,573,800 | 100 | 16,400 |
| " 20...... | 0 | 0 | 0 | 0 | 0 | 487,120 | 0 | 16,600 |
| " 27...... | 200 | 0 | 0 | 0 | 0 | 490,600 | 200 | 28,000 |
| Average...... | 7,194 | 1,158 | 368 | 4,871 | 4,760 | 15,812,346 | 630 | 26,546 |

TABLE I—*continued.*

ORGANISMS PER CUBIC METER IN PLANKTON OF ILLINOIS RIVER IN 1898.

(An asterisk at head of column indicates that all entries in it are based on filter-paper collections.)

| 1898 | *Codonella cratera* | *Halteria grandinella** | *Stentor cœruleus* | *Tintinnidium fluviatile* | Total *Suctoria* | *Metacineta mystacina* | Total *Rotifera* | Total *Rhizota* |
|---|---|---|---|---|---|---|---|---|
| Jan. 11...... | 300 | 80,000 | 300 | 0 | 0 | 0 | 6,580 | 0 |
| " 21...... | 300 | 40,000 | 28,800 | 0 | 100 | 0 | 49,240 | 0 |
| " 25...... | 58,437 | 0 | 11,997 | 0 | 0 | 0 | 126,603 | 0 |
| Feb. 3...... | 5,900 | 0 | 1,000 | 0 | 0 | 0 | 11,496 | 0 |
| " 8...... | 8,000 | 0 | 800 | 0 | 0 | 0 | 14,160 | 0 |
| " 15...... | 5,200 | 0 | 800 | 0 | 0 | 0 | 31,040 | 0 |
| " 22...... | 15,795 | 720,000 | 0 | 0 | 0 | 0 | 48,649 | 0 |
| Mar. 1...... | 10,000 | 0 | 0 | 0 | 1,600 | 1,600 | 20,400 | 400 |
| " 8...... | 8,400 | 0 | 520 | 0 | 1,600 | 1,600 | 29,200 | 800 |
| " 15...... | 33,200 | 0 | 1,000 | 0 | 400 | 400 | 103,940 | 400 |
| " 22...... | 41,600 | 60,000 | 80 | 0 | 1,200 | 1,200 | 185,520 | 400 |
| " 29...... | 30,400 | 0 | 0 | 0 | 200 | 200 | 115,880 | 5,020 |
| Apr. 5...... | 20,500 | 0 | 20 | 300 | 100 | 0 | 84,820 | 1,800 |
| " 12...... | 20,100 | 900,000 | 0 | 200 | 100 | 0 | 54,540 | 0 |
| " 19...... | 453,600 | 0 | 0 | 400 | 0 | 0 | 749,000 | 0 |
| " 26...... | 614,400 | 0 | 0 | 12,800 | 0 | 0 | 2,892,360 | 4,800 |
| May 3...... | 736,000 | 0 | 0 | 720,000 | 0 | 0 | 5,247,800 | 0 |
| " 10...... | 78,400 | 0 | 0 | 24,000 | 0 | 0 | 2,663,400 | 200 |
| " 17...... | 72,000 | 0 | 0 | 10,400 | 800 | 800 | 1,465,500 | 800 |
| " 24...... | 74,200 | 0 | 0 | 400 | 0 | 0 | 196,020 | 3,200 |
| " 31...... | 61,200 | 0 | 0 | 400 | 200 | 200 | 180,760 | 18,800 |
| June 7...... | 1,499,200 | 60,000 | 0 | 14,400 | 0 | 0 | 903,000 | 392,000 |
| " 14...... | 532,800 | 0 | 0 | 104,000 | 0 | 0 | 639,600 | 1,600 |
| " 21...... | 195,200 | 0 | 0 | 74,400 | 800 | 0 | 2,601,200 | 3,200 |
| " 28...... | 45,600 | 3,600,000 | 0 | 33,600 | 0 | 0 | 1,118,400 | 0 |
| July 5...... | 13,600 | 0 | 0 | 4,800 | 7,200 | 7,200 | 153,000 | 800 |
| " 12...... | 35,600 | 2,700,000 | 0 | 5,600 | 400 | 400 | 184,500 | 0 |
| " 19...... | 24,000 | 0 | 0 | 2,800 | 400 | 400 | 946,080 | 0 |
| " 26...... | 2,000 | 120,000 | 0 | 3,600 | 0 | 0 | 370,200 | 0 |
| Aug. 2...... | 23,200 | 1,800,000 | 0 | 95,200 | 0 | 0 | 1,294,240 | 0 |
| " 9...... | 8,400 | 0 | 0 | 4,800 | 0 | 0 | 782,720 | 0 |
| " 16...... | 20,000 | 0 | 0 | 8,800 | 0 | 0 | 935,380 | 0 |
| " 23...... | 26,400 | 0 | 0 | 5,600 | 1,600 | 1,600 | 696,180 | 1,600 |
| " 30...... | 51,200 | 0 | 0 | 800 | 0 | 0 | 435,080 | 1,600 |
| Sept. 6...... | 13,600 | 0 | 40 | 0 | 0 | 0 | 422,840 | 0 |
| " 13...... | 49,000 | 0 | 120 | 2,000 | 0 | 0 | 197,960 | 0 |
| " 20...... | 34,500 | 0 | 0 | 20,000 | 500 | 0 | 475,860 | 1,000 |
| " 27...... | 92,800 | 0 | 200 | 22,400 | 0 | 0 | 1,792,700 | 14,400 |
| Oct. 4...... | 23,000 | 0 | 0 | 1,500 | 0 | 0 | 105,020 | 2,580 |
| " 11...... | 23,000 | 0 | 40 | 500 | 0 | 0 | 122,000 | 2,000 |
| " 18...... | 47,000 | 900,000 | 0 | 1,000 | 40 | 40 | 159,200 | 0 |
| " 25...... | 23,000 | 0 | 0 | 0 | 0 | 0 | 1,048,620 | 0 |
| Nov. 1...... | 12,500 | 0 | 60 | 0 | 0 | 0 | 156,300 | 0 |
| " 8...... | 70,000 | 0 | 0 | 0 | 0 | 0 | 147,780 | 0 |
| " 15...... | 35,000 | 0 | 100 | 0 | 0 | 0 | 180,600 | 0 |
| " 22...... | 2,000 | 0 | 0 | 0 | 0 | 0 | 128,400 | 0 |
| " 29...... | 2,000 | 0 | 0 | 0 | 0 | 0 | 66,000 | 0 |
| Dec. 6...... | 40 | 0 | 0 | 0 | 0 | 0 | 64,280 | 0 |
| " 13...... | 300 | 1,080,000 | 0 | 0 | 0 | 0 | 159,740 | 0 |
| " 20...... | 200 | 120,000 | 0 | 0 | 0 | 0 | 191,320 | 0 |
| " 27...... | 200 | 120,000 | 0 | 0 | 0 | 0 | 50,540 | 200 |
| Average...... | 101,024 | 255,769 | 882 | 22,590 | 332 | 301 | 592,416 | |

# TABLE I—*continued.*

## ORGANISMS PER CUBIC METER IN PLANKTON OF ILLINOIS RIVER IN 1898.

(An asterisk at head of column indicates that all entries in it are based on filter-paper collections.)

| 1898 | *Conochilus dossuarius* | *Conochilus unicornis* | Total *Bdelloida* | *Philodina megalotrocha* | *Rotifer neptunius* | *Rotifer tardus* | Total *Ploima* | *Anuræa aculeata* |
|---|---|---|---|---|---|---|---|---|
| Jan. 11...... | 0 | 0 | 400 | 0 | 0 | 400 | 6,180 | 0 |
| " 21...... | 0 | 0 | 45,100 | 0 | 0 | 44,500 | 4,040 | 0 |
| " 25...... | 0 | 0 | 90,171 | 0 | 0 | 89,379 | 35,271 | 0 |
| Feb. 3...... | 0 | 0 | 3,800 | 0 | 0 | 3,800 | 7,696 | 0 |
| " 8...... | 0 | 0 | 6,800 | 0 | 0 | 6,800 | 7,360 | 0 |
| " 15...... | 0 | 0 | 18,000 | 0 | 0 | 27,000 | 12,240 | 0 |
| " 22...... | 0 | 0 | 25,272 | 0 | 0 | 25,272 | 23,377 | 0 |
| Mar. 1...... | 0 | 0 | 1,600 | 0 | 400 | 800 | 18,320 | 0 |
| " 8...... | 400 | 0 | 4,040 | 0 | 40 | 4,000 | 23,960 | 400 |
| " 15...... | 0 | 400 | 22,160 | 80 | 400 | 19,200 | 80,980 | 40 |
| " 22...... | 0 | 400 | 10,440 | 0 | 40 | 10,400 | 174,680 | 400 |
| " 29...... | 0 | 20 | 1,620 | 0 | 20 | 1,600 | 109,240 | 200 |
| Apr. 5...... | 0 | 0 | 1,100 | 0 | 0 | 1,100 | 81,920 | 600 |
| " 12...... | 0 | 0 | 960 | 0 | 60 | 800 | 53,480 | 600 |
| " 19...... | 0 | 400 | 3,300 | 400 | 100 | 16,000 | 745,300 | 2,000 |
| " 26...... | 0 | 3,200 | 4,640 | 0 | 640 | 3,200 | 2,889,720 | 3,200 |
| May 3...... | 0 | 0 | 16,000 | 0 | 0 | 12,800 | 5,231,800 | 22,400 |
| " 10...... | 0 | 200 | 14,400 | 0 | 1,600 | 11,200 | 2,647,200 | 35,600 |
| " 17...... | 0 | 800 | 20,800 | 0 | 6,400 | 10,400 | 1,438,300 | 22,400 |
| " 24...... | 0 | 3,200 | 1,040 | 80 | 520 | 400 | 191,780 | 4,000 |
| " 31...... | 0 | 18,600 | 880 | 80 | 200 | 600 | 161,080 | 1,400 |
| June 7...... | 0 | 392,000 | 800 | 0 | 800 | 0 | 507,000 | 1,600 |
| " 14...... | 0 | 1,600 | 600 | 0 | 400 | 200 | 637,400 | 800 |
| " 21...... | 3,200 | 0 | 1,100 | 0 | 300 | 800 | 2,593,600 | 0 |
| " 28...... | 0 | 0 | 1,900 | 0 | 800 | 300 | 1,112,500 | 0 |
| July 5...... | 0 | 800 | 2,480 | 80 | 1,600 | 800 | 146,920 | 0 |
| " 12...... | 0 | 0 | 4,800 | 400 | 2,000 | 2,400 | 178,100 | 0 |
| " 19...... | 0 | 0 | 2,760 | 1,600 | 360 | 800 | 933,320 | 0 |
| " 26...... | 0 | 0 | 120 | 0 | 0 | 60 | 268,480 | 0 |
| Aug. 2...... | 0 | 0 | 1,400 | 0 | 560 | 40 | 1,260,840 | 0 |
| " 9...... | 0 | 0 | 1,200 | 0 | 0 | 12,000 | 775,920 | 0 |
| " 16...... | 0 | 0 | 4,120 | 0 | 120 | 4,000 | 907,260 | 0 |
| " 23...... | 1,600 | 0 | 5,720 | 0 | 60 | 5,600 | 671,260 | 0 |
| " 30...... | 1,600 | 0 | 4,080 | 0 | 80 | 2,400 | 415,000 | 0 |
| Sept. 6...... | 0 | 0 | 9,640 | 2,400 | 40 | 4,800 | 413,200 | 0 |
| " 13...... | 0 | 0 | 21,000 | 500 | 1,500 | 17,500 | 171,960 | 0 |
| " 20...... | 1,000 | 0 | 6,000 | 1,500 | 500 | 3,000 | 460,360 | 0 |
| " 27...... | 14,400 | 0 | 13,300 | 8,000 | 300 | 4,800 | 1,744,200 | 0 |
| Oct. 4...... | 2,500 | 0 | 2,280 | 2,000 | 120 | 160 | 97,160 | 0 |
| " 11...... | 2,000 | 0 | 2,000 | 1,000 | 500 | 500 | 115,500 | 0 |
| " 18...... | 0 | 0 | 540 | 0 | 40 | 0 | 188,160 | 0 |
| " 25...... | 0 | 0 | 3,500 | 0 | 1,000 | 2,500 | 1,045,120 | 0 |
| Nov. 1...... | 0 | 0 | 3,060 | 0 | 60 | 3,000 | 152,680 | 0 |
| " 8...... | 0 | 0 | 1,180 | 120 | 60 | 1,000 | 146,600 | 0 |
| " 15...... | 0 | 0 | 100 | 0 | 100 | 0 | 180,500 | 0 |
| " 22...... | 0 | 0 | 400 | 0 | 400 | 0 | 126,000 | 0 |
| " 29...... | 0 | 0 | 0 | 0 | 0 | 0 | 66,000 | 0 |
| Dec. 6...... | 0 | 0 | 20 | 0 | 0 | 20 | 64,260 | 0 |
| " 13...... | 0 | 0 | 600 | 0 | 0 | 600 | 159,140 | 0 |
| " 20...... | 0 | 0 | 0 | 0 | 0 | 0 | 191,320 | 0 |
| " 27...... | 200 | 0 | 20 | 0 | 20 | 0 | 50,120 | 20 |
| Average...... | 517 | 8,108 | 405,983 | 351 | 425 | 6,688 | 571,611 | 1,839 |

TABLE I—*continued.*

ORGANISMS PER CUBIC METER IN PLANKTON OF ILLINOIS RIVER IN 1898.

(An asterisk at head of column indicates that all entries in it are based on filter-paper collections.)

| 1898 | *Anuræa cochlearis* type and var. *macracantha* | *Anuræa cochlearis* var. *stipitata* | *Anuræa cochlearis* var. *tecta* | Total *Anuræa cochlearis* | Total eggs *Anuræa cochlearis* | *Anuræa hypelasma* | Total eggs *Anuræa hypelasma* |
|---|---|---|---|---|---|---|---|
| Jan. 11...... | 0 | 0 | 0 | 0 | 0 | 100 | 100 |
| " 21...... | 300 | 0 | 0 | 300 | 100 | 0 | 0 |
| " 25...... | 387 | 0 | 1,661 | 2,048 | 0 | 0 | 0 |
| Feb. 3...... | 500 | 0 | 100 | 600 | 300 | 0 | 0 |
| " 8...... | 0 | 0 | 80 | 80 | 0 | 0 | 0 |
| " 15...... | 80 | 0 | 0 | 80 | 0 | 0 | 0 |
| " 22...... | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Mar. 1...... | 400 | 0 | 80 | 480 | 0 | 0 | 0 |
| " 8...... | 800 | 0 | 1,200 | 2,000 | 1,600 | 0 | 0 |
| " 15...... | 2,200 | 0 | 600 | 2,800 | 1,400 | 0 | 0 |
| " 22...... | 3,200 | 0 | 800 | 4,000 | 2,800 | 0 | 0 |
| " 29...... | 2,600 | 0 | 600 | 3,200 | 200 | 0 | 0 |
| Apr. 5...... | 0 | 1,700 | 400 | 2,100 | 600 | 0 | 0 |
| " 12...... | 1,800 | 0 | 400 | 2,200 | 800 | 0 | 0 |
| " 19...... | 12,400 | 0 | 2,800 | 15,200 | 8,800 | 0 | 400 |
| " 26...... | 12,800 | 121,000 | 4,000 | 137,800 | 57,800 | 0 | 0 |
| May 3...... | 222,400 | 745,600 | 54,400 | 1,022,400 | 552,200 | 0 | 0 |
| " 10...... | 134,400 | 790,400 | 220,800 | 1,145,600 | 643,200 | 0 | 0 |
| " 17...... | 91,200 | 295,600 | 48,000 | 434,800 | 160,000 | 0 | 0 |
| " 24...... | 1,000 | 18,400 | 1,800 | 21,200 | 7,200 | 0 | 0 |
| " 31...... | 1,400 | 9,200 | 600 | 11,200 | 3,400 | 0 | 0 |
| June 7...... | 0 | 32,000 | 0 | 32,000 | 3,200 | 0 | 0 |
| " 14...... | 0 | 28,000 | 1,600 | 29,600 | 7,800 | 0 | 2,400 |
| " 21...... | 0 | 150,400 | 222,400 | 372,800 | 148,800 | 9,600 | 8,800 |
| " 28...... | 0 | 48,800 | 117,600 | 166,400 | 20,800 | 7,200 | 4,000 |
| July 5...... | 0 | 2,800 | 7,200 | 10,000 | 1,600 | 800 | 400 |
| " 12...... | 0 | 2,000 | 8,000 | 10,000 | 4,000 | 1,200 | 0 |
| " 19...... | 0 | 2,000 | 15,200 | 17,200 | 5,600 | 4,000 | 0 |
| " 26...... | 0 | 0 | 1,200 | 1,200 | 0 | 0 | 0 |
| Aug. 2...... | 0 | 0 | 0 | 0 | 0 | 4,800 | 2,400 |
| " 9...... | 0 | 0 | 0 | 0 | 0 | 2,000 | 4,000 |
| " 16...... | 0 | 0 | 0 | 0 | 0 | 16,000 | 8,800 |
| " 23...... | 0 | 0 | 0 | 0 | 0 | 9,600 | 3,200 |
| " 30...... | 0 | 0 | 0 | 0 | 0 | 800 | 800 |
| Sept. 6...... | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| " 13...... | 0 | 500 | 0 | 500 | 0 | 1,000 | 0 |
| " 20...... | 0 | 3,500 | 8,500 | 12,000 | 6,000 | 4,000 | 1,000 |
| " 27...... | 0 | 19,200 | 35,200 | 54,400 | 16,000 | 43,200 | 54,400 |
| Oct. 4...... | 0 | 4,000 | 2,000 | 4,000 | 500 | 2,000 | 500 |
| " 11...... | 0 | 7,000 | 2,000 | 9,000 | 4,500 | 500 | 0 |
| " 18...... | 0 | 17,500 | 7,000 | 24,500 | 10,500 | 3,500 | 2,500 |
| " 25...... | 500 | 9,000 | 19,000 | 28,500 | 7,000 | 13,500 | 5,000 |
| Nov. 1...... | 500 | 0 | 1,000 | 1,500 | 0 | 500 | 1,000 |
| " 8...... | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| " 15...... | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| " 22...... | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| " 29...... | 500 | 1,000 | 8,500 | 10,000 | 500 | 0 | 0 |
| Dec. 6...... | 0 | 1,000 | 1,020 | 2,200 | 20 | 0 | 0 |
| " 13...... | 500 | 1,700 | 5,100 | 7,300 | 1,800 | 0 | 0 |
| " 20...... | 0 | 3,600 | 1,600 | 5,200 | 2,600 | 0 | 0 |
| " 27...... | 0 | 200 | 0 | 200 | 0 | 0 | 0 |
| Average...... | 9,421 | 44,540 | 15,432 | 69,165 | 32,358 | 2,390 | 1,917 |

## TABLE I—*continued.*

ORGANISMS PER CUBIC METER IN PLANKTON OF ILLINOIS RIVER IN 1898.

(An asterisk at head of column indicates that all entries in it are based on filter-paper collections.)

| 1898 | *Asplanchna brightwellii* | *Asplanchna priodonta* | *Brachionus angularis* | *Brachionus angularis* var. *bidens* | Total *Brachionus angularis* | Total eggs *Brachionus angularis* | *Brachionus bakeri* var. *brevispinus* |
|---|---|---|---|---|---|---|---|
| Jan. 11...... | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| " 21...... | 100 | 0 | 0 | 0 | 0 | 0 | 0 |
| " 25...... | 0 | 0 | 387 | 0 | 387 | 0 | 0 |
| Feb. 3...... | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| " 8...... | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| " 15...... | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| " 22...... | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Mar. 1...... | 80 | 0 | 0 | 0 | 0 | 0 | 0 |
| " 8...... | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| " 15...... | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| " 22...... | 0 | 0 | 0 | 0 | 0 | 0 | 40 |
| " 29...... | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Apr. 5...... | 20 | 0 | 100 | 0 | 100 | 0 | 0 |
| " 12...... | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| " 19...... | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| " 26...... | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| May 3...... | 16,000 | 0 | 0 | 0 | 0 | 0 | 0 |
| " 10...... | 20,800 | 3,200 | 1,600 | 0 | 1,600 | 0 | 0 |
| " 17...... | 11,200 | 14,400 | 0 | 800 | 800 | 800 | 0 |
| " 24...... | 400 | 2,120 | 0 | 200 | 200 | 0 | 0 |
| " 31...... | 200 | 2,000 | 1,400 | 0 | 1,400 | 0 | 0 |
| June 7...... | 200 | 0 | 4,800 | 0 | 4,800 | 0 | 0 |
| " 14...... | 0 | 0 | 4,000 | 0 | 4,000 | 1,600 | 0 |
| " 21...... | 1,100 | 1,100 | 70,400 | 0 | 70,400 | 24,800 | 0 |
| " 28...... | 100 | 0 | 544,000 | 0 | 544,000 | 128,800 | 0 |
| July 5...... | 160 | 0 | 29,200 | 400 | 29,600 | 1,600 | 0 |
| " 12...... | 0 | 0 | 51,200 | 0 | 51,200 | 13,200 | 400 |
| " 19...... | 280 | 0 | 300,800 | 34,800 | 335,600 | 72,800 | 0 |
| " 26...... | 17,900 | 0 | 6,400 | 10,400 | 16,800 | 1,200 | 0 |
| Aug. 2...... | 23,200 | 0 | 10,400 | 93,600 | 103,200 | 12,000 | 0 |
| " 9...... | 80 | 0 | 229,200 | 64,800 | 292,600 | 105,600 | 400 |
| " 16...... | 800 | 0 | 272,800 | 80,800 | 353,600 | 116,000 | 0 |
| " 23...... | 4,000 | 0 | 77,600 | 138,400 | 216,000 | 42,400 | 0 |
| " 30...... | 2,400 | 0 | 28,800 | 86,400 | 115,200 | 28,000 | 2,400 |
| Sept. 6...... | 0 | 0 | 80,000 | 83,200 | 163,200 | 35,200 | 400 |
| " 13...... | 0 | 60 | 27,000 | 10,000 | 36,500 | 18,000 | 2,000 |
| " 20...... | 1,140 | 60 | 87,500 | 27,500 | 115,000 | 43,000 | 0 |
| " 27...... | 6,400 | 0 | 409,600 | 84,800 | 494,400 | 41,600 | 1,600 |
| Oct. 4...... | 500 | 0 | 19,000 | 9,000 | 28,000 | 2,000 | 0 |
| " 11...... | 1,000 | 0 | 8,000 | 1,000 | 9,000 | 2,000 | 0 |
| " 18...... | 0 | 0 | 8,000 | 500 | 8,500 | 2,500 | 0 |
| " 25...... | 60 | 0 | 11,500 | 0 | 11,500 | 5,500 | 0 |
| Nov. 1...... | 0 | 0 | 1,000 | 0 | 1,000 | 0 | 0 |
| " 8...... | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| " 15...... | 0 | 0 | 100 | 0 | 100 | 0 | 0 |
| " 22...... | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| " 29...... | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Dec. 6...... | 0 | 0 | 20 | 0 | 20 | 0 | 0 |
| " 13...... | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| " 20...... | 0 | 0 | 400 | 0 | 400 | 0 | 0 |
| " 27...... | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Average...... | 2,079 | 441 | 43,946 | 13,973 | 57,919 | 13,242 | 139 |

TABLE I—*continued.*

ORGANISMS PER CUBIC METER IN PLANKTON OF ILLINOIS RIVER IN 1898.

(An asterisk at head of column indicates that all entries in it are based on filter-paper collections.)

| 1898 | *Brachionus bakeri* var. *clunior-bicularis* | *Brachionus bakeri* var. *melhemi* | *Brachionus bakeri* var. *obesus* | *Brachionus bakeri* var. *rhenanus* | *Brachionus bakeri* var. *tuberculus* | Total *Brachionus bakeri* | Total eggs *Brachionus bakeri* |
|---|---|---|---|---|---|---|---|
| Jan. 11...... | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| " 21...... | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| " 25...... | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Feb. 3...... | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| " 8...... | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| " 15...... | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| " 22...... | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Mar. 1...... | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| " 8...... | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| " 15...... | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| " 22...... | 0 | 0 | 0 | 0 | 0 | 40 | 0 |
| " 29...... | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Apr. 5...... | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| " 12...... | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| " 19...... | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| " 26...... | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| May 3...... | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| " 10...... | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| " 17...... | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| " 24...... | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| " 31...... | 40 | 0 | 0 | 0 | 0 | 40 | 0 |
| June 7...... | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| " 14...... | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| " 21...... | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| " 28...... | 800 | 0 | 0 | 0 | 100 | 900 | 0 |
| July 5...... | 400 | 0 | 0 | 0 | 400 | 800 | 400 |
| " 12...... | 0 | 60 | 0 | 0 | 1,200 | 1,660 | 60 |
| " 19...... | 920 | 1,200 | 40 | 0 | 0 | 2,160 | 2,520 |
| " 26...... | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Aug. 2...... | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| " 9...... | 400 | 0 | 0 | 40 | 0 | 840 | 800 |
| " 16...... | 800 | 0 | 0 | 1,600 | 0 | 2,400 | 5,600 |
| " 23...... | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| " 30...... | 0 | 800 | 800 | 800 | 800 | 5,600 | 2,400 |
| Sept. 6...... | 800 | 0 | 800 | 1,600 | 4,000 | 7,600 | 5,600 |
| " 13...... | 500 | 0 | 0 | 2,000 | 0 | 4,500 | 4,000 |
| " 20...... | 0 | 500 | 0 | 0 | 0 | 500 | 500 |
| " 27...... | 0 | 0 | 0 | 0 | 1,600 | 3,200 | 0 |
| Oct. 4...... | 40 | 0 | 0 | 0 | 0 | 0 | 0 |
| " 11...... | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| " 18...... | 0 | 0 | 0 | 40 | 0 | 40 | 0 |
| " 25...... | 0 | 0 | 500 | 0 | 0 | 500 | 0 |
| Nov. 1...... | 0 | 0 | 0 | 60 | 0 | 60 | 0 |
| " 8...... | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| " 15...... | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| " 22...... | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| " 29...... | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Dec. 6...... | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| " 13...... | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| " 20...... | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| " 27...... | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Average...... | 90 | 49 | 41 | 118 | 155 | 592 | 420 |

TABLE I—*continued.*

ORGANISMS PER CUBIC METER IN PLANKTON OF ILLINOIS RIVER IN 1898.

(An asterisk at head of column indicates that all entries in it are based on filter-paper collections.)

| 1898 | *Brachionus budapestinensis* | *Brachionus militaris* | *Brachionus mollis* | *Brachionus pala* | *Brachionus pala* var. *amphiceros* | *Brachionus pala* var. *dorcas* | *Brachionus pala* var. *dorcas forma spinosus* | Total *Brachionus pala* |
|---|---|---|---|---|---|---|---|---|
| Jan. 11...... | 0 | 0 | 0 | 20 | 20 | 20 | 0 | 60 |
| " 21...... | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 100 |
| " 25...... | 0 | 0 | 0 | 0 | 0 | 387 | 0 | 387 |
| Feb. 3...... | 0 | 0 | 0 | 0 | 0 | 200 | 0 | 200 |
| " 8...... | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| " 15...... | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| " 22...... | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Mar. 1...... | 0 | 0 | 0 | 80 | 0 | 0 | 0 | 80 |
| " 8...... | 0 | 0 | 0 | 0 | 0 | 80 | 0 | 80 |
| " 15...... | 0 | 0 | 0 | 160 | 0 | 360 | 0 | 520 |
| " 22...... | 0 | 0 | 0 | 0 | 0 | 1,720 | 0 | 1,720 |
| " 29...... | 0 | 0 | 0 | 200 | 0 | 140 | 0 | 340 |
| Apr. 5...... | 0 | 0 | 0 | 0 | 20 | 100 | 0 | 120 |
| " 12...... | 0 | 0 | 0 | 200 | 120 | 160 | 0 | 480 |
| " 19...... | 0 | 0 | 0 | 2,800 | 1,200 | 800 | 0 | 4,800 |
| " 26...... | 0 | 0 | 0 | 57,920 | 97,600 | 4,000 | 0 | 159,520 |
| May 3...... | e | 0 | 0 | 32,000 | 419,200 | 0 | 0 | 451,200 |
| " 10...... | 0 | 0 | 0 | 19,200 | 57,600 | 0 | 0 | 76,800 |
| " 17...... | 0 | 0 | 0 | 5,600 | 69,600 | 800 | 1,700 | 77,700 |
| " 24...... | 0 | 200 | 0 | 80 | 200 | 0 | 0 | 280 |
| " 31...... | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| June 7...... | 0 | 0 | 0 | 200 | 0 | 0 | 0 | 200 |
| " 14...... | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1,000 |
| " 21...... | 0 | 0 | 0 | 800 | 200 | 0 | 0 | 0 |
| " 28...... | 4,000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| July 5...... | 3,600 | 40 | 0 | 40 | 0 | 0 | 0 | 40 |
| " 12...... | 10,000 | 120 | 0 | 0 | 0 | 0 | 0 | 0 |
| " 19...... | 85,600 | 80 | 0 | 800 | 5,600 | 0 | 0 | 6,400 |
| " 26...... | 3,200 | 0 | 0 | 0 | 120 | 0 | 0 | 120 |
| Aug. 2...... | 9,600 | 0 | 40 | 0 | 6,400 | 0 | 0 | 6,400 |
| " 9...... | 11,200 | 0 | 200 | 1,200 | 2,000 | 0 | 0 | 3,200 |
| " 16...... | 20,000 | 0 | 800 | 800 | 37,600 | 0 | 0 | 38,400 |
| " 23...... | 8,000 | 800 | 0 | 0 | 35,200 | 0 | 0 | 35,200 |
| " 30...... | 7,200 | 3,200 | 800 | 800 | 32,000 | 0 | 0 | 32,800 |
| Sept. 6...... | 7,200 | 1,600 | 0 | 0 | 19,200 | 0 | 0 | 19,200 |
| " 13...... | 1,500 | 0 | 0 | 500 | 4,000 | 0 | 0 | 4,500 |
| " 20...... | 2,000 | 0 | 500 | 500 | 9,000 | 0 | 0 | 9,500 |
| " 27...... | 44,800 | 1,600 | 4,800 | 4,800 | 78,400 | 0 | 0 | 83,200 |
| Oct. 4...... | 80 | 0 | 0 | 40 | 1,000 | 0 | 0 | 1,040 |
| " 11...... | 0 | 0 | 0 | 500 | 0 | 0 | 0 | 500 |
| " 18...... | 1,000 | 0 | 0 | 500 | 80 | 0 | 0 | 580 |
| " 25...... | 0 | 0 | 0 | 3,500 | 5,000 | 0 | 0 | 8,500 |
| Nov. 1...... | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| " 8...... | 0 | 0 | 0 | 0 | 180 | 0 | 0 | 180 |
| " 15...... | 0 | 0 | 0 | 1,000 | 100 | 0 | 0 | 1,100 |
| " 22...... | 0 | 0 | 0 | 400 | 400 | 0 | 0 | 800 |
| " 29...... | 0 | 0 | 0 | 1,000 | 500 | 0 | 0 | 1,500 |
| Dec. 6...... | 0 | 0 | 0 | 320 | 1,160 | 20 | 0 | 1,500 |
| " 13...... | 0 | 0 | 0 | 2,400 | 3,200 | 0 | 0 | 5,600 |
| " 20...... | 0 | 0 | 0 | 1,200 | 606 | 0 | 0 | 1,800 |
| " 27...... | 0 | 0 | 0 | 400 | 200 | 40 | 0 | 640 |
| Average...... | 4,211 | 147 | 137 | 2,693 | 17,071 | 170 | 33 | 19,969 |

TABLE I—*continued*.

ORGANISMS PER CUBIC METER IN PLANKTON OF ILLINOIS RIVER IN 1898.

(An asterisk at head of column indicates that all entries in it are based on filter-paper collections.)

| 1898 | Total eggs *Brachionus pala* | *Brachionus urceolaris* | *Brachionus urceolaris* var. *bursarius* | *Brachionus urceolaris* var. *rubens* | Total *Brachionus urceolaris* | Total eggs *Brachionus urceolaris* | *Brachionus variabilis* | *Brachionus* free winter eggs |
|---|---|---|---|---|---|---|---|---|
| Jan. 11...... | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 100 |
| " 21...... | 100 | 0 | 0 | 40 | 40 | 0 | 0 | 0 |
| " 25...... | 1,161 | 0 | 0 | 0 | 0 | 0 | 0 | 1,548 |
| Feb. 3...... | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 100 |
| " 8...... | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| " 15...... | 800 | 0 | 0 | 0 | 0 | 0 | 0 | 2,400 |
| " 22...... | 632 | 0 | 0 | 0 | 0 | 0 | 0 | 3,791 |
| Mar. 1...... | 480 | 0 | 0 | 80 | 80 | 0 | 0 | 480 |
| " 8...... | 160 | 0 | 0 | 0 | 0 | 0 | 0 | 840 |
| " 15...... | 1,000 | 0 | 0 | 160 | 160 | 0 | 0 | 400 |
| " 22...... | 2,920 | 0 | 0 | 2,000 | 2,000 | 400 | 0 | 440 |
| " 29...... | 420 | 0 | 0 | 1,800 | 1,800 | 1,200 | 0 | 20 |
| Apr. 5...... | 20 | 0 | 0 | 700 | 700 | 400 | 0 | 120 |
| " 12...... | 240 | 0 | 0 | 140 | 140 | 60 | 0 | 200 |
| " 19...... | 5,200 | 0 | 0 | 400 | 400 | 0 | 0 | 0 |
| " 26...... | 324,280 | 0 | 0 | 6,400 | 6,400 | 0 | 0 | 0 |
| May 3...... | 661,200 | 0 | 0 | 0 | 0 | 0 | 0 | 41,600 |
| " 10...... | 118,400 | 0 | 0 | 0 | 0 | 0 | 0 | 9,600 |
| " 17...... | 101,700 | 0 | 0 | 0 | 0 | 0 | 0 | 800 |
| " 24...... | 1,040 | 0 | 0 | 0 | 0 | 0 | 200 | 80 |
| " 31...... | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 400 |
| June 7...... | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| " 14...... | 400 | 0 | 0 | 0 | 0 | 0 | 0 | 400 |
| " 21...... | 100 | 800 | 0 | 0 | 800 | 0 | 0 | 0 |
| " 28...... | 100 | 100 | 0 | 0 | 100 | 0 | 0 | 100 |
| July 5...... | 40 | 0 | 0 | 0 | 0 | 0 | 0 | 40 |
| " 12...... | 400 | 0 | 0 | 0 | 0 | 0 | 0 | 1,200 |
| " 19...... | 400 | 40 | 200 | 0 | 240 | 0 | 0 | 400 |
| " 26...... | 800 | 0 | 400 | 0 | 400 | 0 | 0 | 1,200 |
| Aug. 2...... | 1,200 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| " 9...... | 8,400 | 0 | 800 | 0 | 800 | 0 | 0 | 0 |
| " 16...... | 5,600 | 0 | 800 | 0 | 800 | 0 | 0 | 800 |
| " 23...... | 14,400 | 0 | 2,400 | 0 | 2,400 | 800 | 0 | 4,800 |
| " 30...... | 12,000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Sept. 6...... | 22,400 | 0 | 5,600 | 0 | 5,600 | 0 | 0 | 800 |
| " 13...... | 3,000 | 0 | 500 | 0 | 500 | 0 | 0 | 0 |
| " 20...... | 5,500 | 0 | 0 | 0 | 0 | 0 | 0 | 500 |
| " 27...... | 32,000 | 0 | 0 | 0 | 0 | 0 | 0 | 1,600 |
| Oct. 4...... | 500 | 0 | 0 | 0 | 0 | 0 | 0 | 500 |
| " 11...... | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 500 |
| " 18...... | 500 | 0 | 0 | 0 | 0 | 0 | 0 | 540 |
| " 25...... | 4,500 | 0 | 0 | 0 | 0 | 0 | 0 | 500 |
| Nov. 1...... | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2,000 |
| " 8...... | 120 | 0 | 0 | 0 | 0 | 0 | 0 | 2,000 |
| " 15...... | 1,200 | 0 | 0 | 0 | 0 | 0 | 0 | 1,000 |
| " 22...... | 2,400 | 0 | 0 | 0 | 0 | 0 | 0 | 2,000 |
| " 29...... | 1,500 | 0 | 0 | 0 | 0 | 0 | 0 | 500 |
| Dec. 6...... | 860 | 0 | 0 | 100 | 100 | 0 | 0 | 0 |
| " 13...... | 10,600 | 0 | 0 | 600 | 600 | 0 | 0 | 0 |
| " 20...... | 1,800 | 0 | 0 | 40 | 40 | 0 | 0 | 0 |
| " 27...... | 100 | 0 | 0 | 240 | 240 | 80 | 0 | 1,621 |
| Average...... | 25,974 | 18 | 206 | 244 | 468 | 56 | 4 | 1,685 |

## TABLE I—*continued.*

### Organisms per Cubic Meter in Plankton of Illinois River in 1898.

(An asterisk at head of column indicates that all entries in it are based on filter-paper collections.)

| 1898 | *Mastigocerca carinata* | *Metopidia solidus* | *Monostyla bulla* | *Monostyla lunaris* | *Notholca striata* var. *acuminata* | *Polyarthra platyptera* | *Polyartha platyptera* Male eggs | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | Free | Carried |
| Jan. 11...... | 0 | 0 | 0 | 0 | 0 | 1,000 | 0 | 0 |
| " 21...... | 0 | 0 | 0 | 100 | 0 | 1,200 | 0 | 0 |
| " 25...... | 0 | 0 | 0 | 0 | 0 | 11,997 | 0 | 0 |
| Feb. 3...... | 0 | 0 | 0 | 0 | 24 | 3,200 | 0 | 0 |
| " 8...... | 0 | 0 | 0 | 0 | 240 | 2,000 | 0 | 0 |
| " 15...... | 0 | 0 | 0 | 0 | 80 | 1,600 | 0 | 0 |
| " 22...... | 0 | 0 | 0 | 0 | 0 | 6,318 | 0 | 0 |
| Mar. 1...... | 400 | 0 | 0 | 0 | 800 | 3,200 | 0 | 0 |
| " 8...... | 0 | 0 | 0 | 0 | 1,200 | 5,200 | 0 | 0 |
| " 15...... | 0 | 0 | 0 | 0 | 6,400 | 22,200 | 0 | 0 |
| " 22...... | 0 | 400 | 0 | 0 | 10,800 | 37,600 | 0 | 1,600 |
| " 29...... | 0 | 0 | 0 | 0 | 200 | 40,400 | 0 | 2,600 |
| Apr. 5...... | 0 | 0 | 100 | 0 | 300 | 42,800 | 1,300 | 2,800 |
| " 12...... | 0 | 100 | 100 | 0 | 0 | 26,700 | 900 | 1,900 |
| " 19...... | 0 | 400 | 400 | 0 | 0 | 148,200 | 8,800 | 1,600 |
| " 26...... | 0 | 0 | 0 | 0 | 0 | 696,000 | 150,400 | 53,800 |
| May 3...... | 0 | 0 | 0 | 0 | 0 | 582,400 | 0 | 19,200 |
| " 10...... | 0 | 0 | 0 | 0 | 0 | 137,600 | 4,800 | 0 |
| " 17...... | 0 | 800 | 0 | 0 | 0 | 195,200 | 12,000 | 2,400 |
| " 24...... | 0 | 0 | 200 | 800 | 0 | 52,200 | 0 | 0 |
| " 31...... | 0 | 0 | 200 | 400 | 0 | 52,400 | 200 | 0 |
| June 7...... | 0 | 0 | 0 | 0 | 0 | 304,000 | 1,600 | 0 |
| " 14...... | 0 | 0 | 0 | 0 | 0 | 432,800 | 0 | 0 |
| " 21...... | 19,200 | 800 | 0 | 0 | 0 | 241,600 | 0 | 0 |
| " 28...... | 11,200 | 800 | 0 | 0 | 0 | 56,800 | 0 | 0 |
| July 5...... | 2,000 | 0 | 0 | 0 | 0 | 6,400 | 0 | 0 |
| " 12...... | 1,600 | 0 | 0 | 0 | 0 | 21,600 | 0 | 0 |
| " 19...... | 7,200 | 0 | 800 | 0 | 0 | 89,200 | 0 | 0 |
| " 26...... | 4,000 | 0 | 800 | 0 | 0 | 86,400 | 0 | 0 |
| Aug. 2...... | 15,200 | 0 | 0 | 0 | 0 | 288,000 | 0 | 0 |
| " 9...... | 4,000 | 0 | 0 | 0 | 0 | 55,200 | 0 | 0 |
| " 16...... | 5,600 | 0 | 0 | 0 | 0 | 84,800 | 0 | 0 |
| " 23...... | 5,600 | 0 | 0 | 0 | 0 | 96,000 | 0 | 0 |
| " 30...... | 800 | 0 | 0 | 0 | 0 | 51,200 | 0 | 0 |
| Sept. 6...... | 0 | 0 | 0 | 0 | 0 | 4,000 | 0 | 0 |
| " 13...... | 2,500 | 0 | 0 | 0 | 0 | 31,000 | 0 | 0 |
| " 20...... | 1,500 | 0 | 0 | 500 | 0 | 72,500 | 0 | 0 |
| " 27...... | 4,800 | 0 | 0 | 0 | 0 | 238,400 | 0 | 1,600 |
| Oct. 4...... | 1,000 | 0 | 0 | 0 | 0 | 24,500 | 0 | 0 |
| " 11...... | 0 | 0 | 0 | 0 | 0 | 47,500 | 5,000 | 500 |
| " 18...... | 0 | 0 | 0 | 0 | 0 | 27,000 | 2,000 | 1,500 |
| " 25...... | 0 | 0 | 0 | 0 | 0 | 37,500 | 0 | 2,000 |
| Nov. 1...... | 60 | 0 | 0 | 0 | 0 | 500 | 0 | 0 |
| " 8...... | 0 | 0 | 0 | 0 | 0 | 1,000 | 0 | 0 |
| " 15...... | 0 | 0 | 0 | 0 | 0 | 2,000 | 0 | 0 |
| " 22...... | 400 | 0 | 0 | 0 | 0 | 6,000 | 0 | 0 |
| " 29...... | 0 | 0 | 0 | 0 | 0 | 1,000 | 0 | 0 |
| Dec. 6...... | 0 | 0 | 0 | 0 | 0 | 6,020 | 0 | 160 |
| " 13...... | 0 | 0 | 0 | 0 | 0 | 42,100 | 100 | 100 |
| " 20...... | 0 | 200 | 0 | 0 | 40 | 63,400 | 0 | 200 |
| " 27...... | 0 | 0 | 0 | 0 | 0 | 19,200 | 0 | 0 |
| Average...... | 1,674 | 67 | 50 | 37 | 388 | 86,674 | 3,598 | 1,768 |

TABLE I—*continued.*

ORGANISMS PER CUBIC METER IN PLANKTON OF ILLINOIS RIVER IN 1898.

(An asterisk at head of column indicates that all entries in it are based on filter-paper collections.)

| 1898 | *Polyarthra platyptera* Winter eggs | | *Polyarthra platyptera* eggs | *Pterodina patina* | *Rattulus tigris* | *Schizocerca diversicornis* | *Synchæta pectinata* | *Synchæta stylata* | Total free winter eggs *Synchæta* |
|---|---|---|---|---|---|---|---|---|---|
| | Free | Carried | | | | | | | |
| Jan. 11...... | 0 | 0 | 2,200 | 0 | 0 | 0 | 0 | 2,120 | 100 |
| " 21...... | 100 | 0 | 1,000 | 0 | 100 | 0 | 0 | 300 | 0 |
| " 25...... | 0 | 0 | 8,127 | 0 | 0 | 0 | 0 | 4,257 | 0 |
| Feb. 3...... | 0 | 0 | 1,700 | 0 | 0 | 0 | 72 | 1,000 | 0 |
| " 8...... | 0 | 0 | 2,800 | 0 | 0 | 0 | 0 | 1,200 | 0 |
| " 15...... | 800 | 0 | 3,200 | 0 | 400 | 0 | 0 | 800 | 1,200 |
| " 22...... | 0 | 0 | 6,318 | 0 | 0 | 0 | 632 | 0 | 0 |
| Mar. 1...... | 0 | 0 | 3,200 | 0 | 0 | 0 | 0 | 6,400 | 0 |
| " 8...... | 0 | 0 | 4,000 | 0 | 0 | 0 | 0 | 4,800 | 0 |
| " 15...... | 200 | 0 | 17,800 | 0 | 40 | 0 | 0 | 15,200 | 160 |
| " 22...... | 0 | 0 | 26,400 | 0 | 400 | 0 | 0 | 58,000 | 0 |
| " 29...... | 200 | 0 | 11,400 | 0 | 100 | 0 | 0 | 47,000 | 0 |
| Apr. 5...... | 100 | 100 | 10,400 | 0 | 300 | 0 | 0 | 21,000 | 0 |
| " 12...... | 0 | 100 | 8,700 | 0 | 200 | 0 | 0 | 11,500 | 0 |
| " 19...... | 1,600 | 0 | 104,200 | 0 | 0 | 0 | 400 | 368,000 | 0 |
| " 26...... | 22,400 | 0 | 502,400 | 0 | 0 | 0 | 1,600 | 954,400 | 6,400 |
| May 3...... | 51,200 | 0 | 316,800 | 0 | 0 | 0 | 0 | 1,139,000 | 9,600 |
| " 10...... | 11,200 | 0 | 72,000 | 0 | 3,200 | 0 | 0 | 233,600 | 6,400 |
| " 17...... | 2,400 | 0 | 120,000 | 0 | 0 | 0 | 800 | 206,400 | 800 |
| " 24...... | 400 | 0 | 28,800 | 200 | 0 | 0 | 200 | 60,480 | 0 |
| " 31...... | 400 | 0 | 10,600 | 40 | 200 | 0 | 600 | 61,600 | 0 |
| June 7...... | 0 | 0 | 96,000 | 1,600 | 0 | 0 | 3,200 | 48,000 | 0 |
| " 14...... | 800 | 0 | 119,200 | 0 | 0 | 0 | 800 | 19,200 | 800 |
| " 21...... | 800 | 0 | 154,400 | 0 | 0 | 0 | 112,000 | 795,200 | 3,200 |
| " 28...... | 800 | 0 | 16,000 | 100 | 0 | 0 | 0 | 22,400 | 0 |
| July 5...... | 400 | 0 | 7,200 | 0 | 40 | 0 | 800 | 22,800 | 400 |
| " 12...... | 400 | 0 | 13,600 | 0 | 400 | 0 | 400 | 9,600 | 800 |
| " 19...... | 800 | 0 | 24,000 | 0 | 0 | 0 | 20,800 | 64,800 | 0 |
| " 26...... | 0 | 0 | 53,600 | 0 | 0 | 0 | 400 | 8,000 | 0 |
| Aug. 2...... | 0 | 0 | 295,200 | 0 | 800 | 800 | 12,000 | 170,400 | 0 |
| " 9...... | 800 | 0 | 84,800 | 0 | 400 | 0 | 4,800 | 52,000 | 800 |
| " 16...... | 0 | 0 | 108,000 | 0 | 800 | 0 | 1,600 | 18,400 | 60 |
| " 23...... | 0 | 0 | 63,200 | 0 | 800 | 0 | 3,200 | 24,800 | 0 |
| " 30...... | 800 | 0 | 47,200 | 0 | 1,600 | 800 | 800 | 1,600 | 0 |
| Sept. 6...... | 0 | 0 | 8,800 | 0 | 0 | 800 | 0 | 0 | 0 |
| " 13...... | 1,000 | 0 | 20,000 | 0 | 0 | 0 | 1,000 | 14,000 | 500 |
| " 20...... | 1,000 | 0 | 103,000 | 0 | 0 | 0 | 4,500 | 27,000 | 500 |
| " 27...... | 1,600 | 1,600 | 86,400 | 0 | 0 | 0 | 30,400 | 265,600 | 100 |
| Oct. 4...... | 1,000 | 0 | 15,000 | 0 | 1,000 | 0 | 500 | 5,000 | 0 |
| " 11...... | 0 | 0 | 5,500 | 0 | 0 | 0 | 0 | 27,000 | 0 |
| " 18...... | 0 | 0 | 14,000 | 0 | 0 | 0 | 500 | 77,000 | 0 |
| " 25...... | 0 | 0 | 17,000 | 0 | 0 | 0 | 0 | 824,500 | 0 |
| Nov. 1...... | 500 | 0 | 4,500 | 0 | 0 | 0 | 0 | 110,500 | 0 |
| " 8...... | 1,000 | 0 | 2,000 | 0 | 0 | 0 | 0 | 97,000 | 60 |
| " 15...... | 1,000 | 0 | 2,000 | 0 | 0 | 0 | 0 | 110,000 | 0 |
| " 22...... | 0 | 0 | 6,000 | 0 | 0 | 0 | 0 | 38,000 | 0 |
| " 29...... | 0 | 0 | 3,000 | 0 | 0 | 0 | 500 | 39,000 | 0 |
| Dec. 6...... | 0 | 0 | 9,160 | 0 | 0 | 0 | 20 | 42,500 | 0 |
| " 13...... | 0 | 0 | 29,300 | 0 | 0 | 0 | 2,500 | 55,720 | 0 |
| " 20...... | 0 | 0 | 52,000 | 0 | 0 | 0 | 0 | 59,200 | 0 |
| " 27...... | 0 | 0 | 11,000 | 0 | 0 | 0 | 400 | 17,640 | 0 |
| Average...... | 1,994 | 34 | 52,560 | 37 | 207 | 46 | 3,950 | 120,391 | 611 |

TABLE I—*continued*.

ORGANISMS PER CUBIC METER IN PLANKTON OF ILLINOIS RIVER IN 1898.

(An asterisk at head of column indicates that all entries in it are based on filter-paper collections.)

| 1898 | Total eggs *Synchæta* | *Triarthra longiseta* | *Triarthra longiseta* eggs | *Pedalion mirum* | Total *Entomostraca* | Total *Ostracoda* | Total *Cladocera* |
|---|---|---|---|---|---|---|---|
| Jan. 11...... | 500 | 0 | 0 | 0 | 700 | 0 | 100 |
| " 21...... | 200 | 0 | 0 | 0 | 1,380 | 0 | 440 |
| " 25...... | 6,579 | 0 | 0 | 0 | 4,788 | 0 | 462 |
| Feb. 3...... | 300 | 0 | 0 | 0 | 216 | 0 | 24 |
| " 8...... | 400 | 0 | 0 | 0 | 320 | 0 | 0 |
| " 15...... | 5,600 | 0 | 0 | 0 | 1,200 | 80 | 0 |
| " 22...... | 0 | 0 | 0 | 0 | 3,285 | 0 | 0 |
| Mar. 1...... | 1,200 | 80 | 0 | 0 | 804 | 0 | 160 |
| " 8...... | 800 | 0 | 0 | 0 | 3,080 | 40 | 80 |
| " 15...... | 3,960 | 0 | 0 | 0 | 12,880 | 40 | 560 |
| " 22...... | 4,000 | 40 | 40 | 0 | 19,440 | 320 | 800 |
| " 29...... | 3,200 | 100 | 0 | 0 | 22,180 | 160 | 360 |
| Apr. 5...... | 1,100 | 300 | 200 | 0 | 34,560 | 200 | 360 |
| " 12...... | 1,000 | 200 | 100 | 0 | 28,060 | 320 | 320 |
| " 19...... | 84,000 | 400 | 0 | 0 | 34,200 | 200 | 400 |
| " 26...... | 38,400 | 3,200 | 0 | 0 | 56,800 | 800 | 1,920 |
| May 3...... | 278,400 | 9,600 | 0 | 0 | 204,800 | 0 | 2,800 |
| " 10...... | 91,600 | 38,400 | 0 | 0 | 235,400 | 400 | 5,600 |
| " 17...... | 56,800 | 17,600 | 3,200 | 0 | 182,300 | 1,600 | 8,500 |
| " 24...... | 9,400 | 600 | 200 | 0 | 167,080 | 400 | 24,080 |
| " 31...... | 12,000 | 1,000 | 0 | 0 | 162,800 | 440 | 51,480 |
| June 7...... | 11,200 | 200 | 0 | 0 | 438,800 | 1,600 | 136,000 |
| " 14...... | 13,600 | 0 | 0 | 0 | 211,400 | 400 | 29,200 |
| " 21...... | 257,600 | 800 | 0 | 100 | 83,100 | 200 | 2,300 |
| " 28...... | 51,200 | 800 | 0 | 500 | 45,600 | 400 | 10,100 |
| July 5...... | 47,200 | 400 | 0 | 1,600 | 4,920 | 440 | 640 |
| " 12...... | 16,800 | 1,600 | 400 | 1,200 | 1,620 | 60 | 360 |
| " 19...... | 34,800 | 4,000 | 0 | 9,200 | 14,040 | 0 | 1,240 |
| " 26...... | 4,800 | 28,000 | 1,600 | 99,600 | 23,000 | 0 | 9,960 |
| Aug. 2...... | 178,400 | 18,400 | 1,600 | 30,400 | 22,160 | 40 | 10,520 |
| " 9...... | 20,000 | 4,400 | 1,200 | 4,000 | 4,120 | 0 | 1,080 |
| " 16...... | 10,460 | 3,200 | 0 | 22,400 | 4,500 | 800 | 1,320 |
| " 23...... | 35,200 | 4,000 | 0 | 17,600 | 17,340 | 180 | 1,820 |
| " 30...... | 7,200 | 6,400 | 0 | 14,400 | 27,080 | 0 | 4,040 |
| Sept. 6...... | 0 | 0 | 0 | 0 | 9,080 | 0 | 720 |
| " 13...... | 9,500 | 1,000 | 0 | 5,000 | 24,720 | 500 | 3,420 |
| " 20...... | 17,500 | 500 | 0 | 5,500 | 21,880 | 0 | 1,560 |
| " 27...... | 38,500 | 14,400 | 3,200 | 19,200 | 99,300 | 0 | 1,100 |
| Oct. 4...... | 0 | 1,500 | 500 | 2,000 | 33,880 | 0 | 1,320 |
| " 11...... | 2,000 | 0 | 0 | 2,000 | 34,060 | 0 | 2,000 |
| " 18...... | 10,500 | 1,500 | 500 | 500 | 25,640 | 0 | 2,120 |
| " 25...... | 78,000 | 500 | 0 | 0 | 26,020 | 0 | 1,020 |
| Nov. 1...... | 29,000 | 0 | 0 | 60 | 8,600 | 0 | 120 |
| " 8...... | 41,060 | 0 | 0 | 0 | 15,080 | 0 | 0 |
| " 15...... | 60,000 | 0 | 0 | 0 | 13,100 | 0 | 100 |
| " 22...... | 66,000 | 0 | 0 | 0 | 13,920 | 320 | 2,800 |
| " 29...... | 500 | 500 | 500 | 0 | 6,180 | 0 | 80 |
| Dec. 6...... | 0 | 0 | 0 | 0 | 9,740 | 0 | 260 |
| " 13...... | 800 | 0 | 0 | 0 | 21,740 | 0 | 240 |
| " 20...... | 2,600 | 0 | 0 | 0 | 2,440 | 0 | 400 |
| " 27...... | 400 | 40 | 0 | 0 | 6,800 | 0 | 280 |
| Average...... | 31,620 | 3,147 | 255 | 4,524 | 47,042 | 191 | 6,241 |

TABLE I—*continued.*

ORGANISMS PER CUBIC METER IN PLANKTON OF ILLINOIS RIVER IN 1898.

(An asterisk at head of column indicates that all entries in it are based on filter-paper collections.)

| 1898 | *Alona affinis* | *Bosmina longirostris* | *Ceriodaphnia scitula* | *Chydorus sphæricus* | *Daphnia cucullata* | *Daphnia hyalina* | *Diaphanosoma brachyurum* | *Moina micrura* |
|---|---|---|---|---|---|---|---|---|
| Jan. 11...... | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 0 |
| " 21...... | 240 | 0 | 0 | 200 | 0 | 0 | 0 | 0 |
| " 25...... | 154 | 308 | 0 | 0 | 0 | 0 | 0 | 0 |
| Feb. 3...... | 0 | 24 | 0 | 0 | 0 | 0 | 0 | 0 |
| " 8...... | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| " 15...... | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| " 22...... | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Mar. 1...... | 0 | 80 | 0 | 80 | 0 | 0 | 0 | 0 |
| " 8...... | 0 | 40 | 0 | 40 | 0 | 0 | 0 | 0 |
| " 15...... | 0 | 120 | 0 | 440 | 0 | 0 | 0 | 0 |
| " 22...... | 0 | 280 | 0 | 480 | 0 | 0 | 0 | 0 |
| " 29...... | 0 | 20 | 20 | 240 | 20 | 0 | 0 | 0 |
| Apr. 5...... | 20 | 100 | 40 | 200 | 0 | 0 | 0 | 0 |
| " 12...... | 20 | 60 | 20 | 200 | 20 | 0 | 0 | 0 |
| " 19...... | 200 | 100 | 0 | 0 | 0 | 0 | 0 | 0 |
| " 26...... | 0 | 800 | 320 | 800 | 0 | 0 | 0 | 0 |
| May 3...... | 0 | 2,800 | 0 | 0 | 0 | 0 | 0 | 0 |
| " 10...... | 0 | 3,600 | 400 | 600 | 600 | 0 | 0 | 0 |
| " 17...... | 200 | 3,500 | 400 | 3,300 | 300 | 0 | 0 | 0 |
| " 24...... | 480 | 5,920 | 2,960 | 7,880 | 440 | 160 | 0 | 0 |
| " 31...... | 40 | 33,920 | 8,720 | 5,040 | 1,000 | 720 | 40 | 0 |
| June 7...... | 200 | 62,800 | 55,800 | 600 | 3,400 | 11,600 | 0 | 0 |
| " 14...... | 0 | 6,000 | 10,600 | 200 | 2,400 | 9,200 | 0 | 0 |
| " 21...... | 100 | 1,500 | 400 | 0 | 100 | 0 | 0 | 200 |
| " 28...... | 200 | 700 | 0 | 0 | 0 | 0 | 0 | 100 |
| July 5...... | 0 | 200 | 0 | 40 | 0 | 0 | 0 | 400 |
| " 12...... | 0 | 180 | 0 | 0 | 0 | 0 | 60 | 120 |
| " 19...... | 0 | 0 | 0 | 160 | 0 | 0 | 40 | 1,040 |
| " 26...... | 0 | 180 | 120 | 0 | 0 | 0 | 8,580 | 1,080 |
| Aug. 2...... | 0 | 40 | 0 | 0 | 0 | 0 | 6,960 | 3,520 |
| " 9...... | 0 | 0 | 0 | 0 | 0 | 0 | 360 | 360 |
| " 16...... | 0 | 0 | 0 | 0 | 0 | 0 | 60 | 1,260 |
| " 23...... | 0 | 0 | 0 | 0 | 0 | 0 | 1,020 | 900 |
| " 30...... | 0 | 0 | 40 | 0 | 0 | 0 | 2,520 | 1,440 |
| Sept. 6...... | 0 | 0 | 40 | 0 | 0 | 0 | 240 | 440 |
| " 13...... | 0 | 0 | 0 | 60 | 0 | 0 | 1,800 | 1,560 |
| " 20...... | 0 | 60 | 0 | 60 | 0 | 0 | 960 | 480 |
| " 27...... | 0 | 0 | 100 | 0 | 0 | 0 | 400 | 500 |
| Oct. 4...... | 0 | 0 | 0 | 40 | 400 | 0 | 880 | 120 |
| " 11...... | 0 | 920 | 0 | 0 | 600 | 0 | 400 | 40 |
| " 18...... | 0 | 1,360 | 0 | 80 | 80 | 0 | 560 | 0 |
| " 25...... | 0 | 840 | 0 | 120 | 60 | 0 | 0 | 0 |
| Nov. 1...... | 0 | 60 | 0 | 60 | 0 | 0 | 0 | 0 |
| " 8...... | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| " 15...... | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 0 |
| " 22...... | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| " 29...... | 0 | 0 | 0 | 80 | 0 | 0 | 0 | 0 |
| Dec. 6...... | 0 | 40 | 20 | 200 | 0 | 0 | 0 | 0 |
| " 13...... | 0 | 140 | 40 | 220 | 0 | 0 | 0 | 0 |
| " 20...... | 0 | 120 | 0 | 160 | 0 | 0 | 0 | 0 |
| " 27...... | 0 | 0 | 0 | 280 | 0 | 0 | 0 | 0 |
| Average...... | 36 | 2,441 | 1,539 | 422 | 181 | 417 | 479 | 261 |

# TABLE I—*continued.*

## ORGANISMS PER CUBIC METER IN PLANKTON OF ILLINOIS RIVER IN 1898

(An asterisk at head of column indicates that all entries in it are based on filter-paper collections.)

| 1898 | Total *Copepoda* | *Canthocamptus* spp. | *Cyclops albidus* | *Cyclops bicuspidatus* | *Cyclops edax* | *Cyclops prasinus* | *Cyclops viridis* var. *brevispinosus* | *Cyclops viridis* var. *insectus* |
|---|---|---|---|---|---|---|---|---|
| Jan. 11...... | 600 | 0 | 0 | 160 | 0 | 0 | 0 | 0 |
| " 21...... | 940 | 40 | 0 | 160 | 0 | 0 | 0 | 40 |
| " 25...... | 4,326 | 77 | 0 | 308 | 0 | 0 | 0 | 308 |
| Feb. 3...... | 192 | 0 | 0 | 48 | 0 | 0 | 0 | 0 |
| " 8...... | 320 | 0 | 0 | 160 | 0 | 0 | 0 | 0 |
| " 15...... | 1,120 | 0 | 0 | 80 | 0 | 0 | 80 | 0 |
| " 22...... | 3,285 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Mar. 1...... | 644 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| " 8...... | 2,960 | 40 | 0 | 120 | 0 | 0 | 0 | 0 |
| " 15...... | 12,280 | 40 | 0 | 400 | 0 | 0 | 80 | 120 |
| " 22...... | 18,320 | 200 | 0 | 80 | 0 | 0 | 0 | 80 |
| " 29...... | 21,660 | 100 | 20 | 60 | 0 | 0 | 20 | 0 |
| Apr. 5...... | 34,000 | 200 | 20 | 40 | 0 | 0 | 0 | 0 |
| " 12...... | 27,420 | 1,120 | 0 | 0 | 0 | 0 | 0 | 40 |
| " 19...... | 33,600 | 0 | 200 | 200 | 0 | 0 | 0 | 500 |
| " 26...... | 54,080 | 0 | 1,600 | 2,880 | 0 | 0 | 0 | 4,160 |
| May 3...... | 202,000 | 400 | 0 | 8,000 | 400 | 0 | 0 | 1,200 |
| " 10...... | 229,400 | 0 | 600 | 5,200 | 0 | 0 | 600 | 2,200 |
| " 17...... | 172,200 | 800 | 200 | 600 | 0 | 0 | 0 | 3,300 |
| " 24...... | 142,600 | 80 | 920 | 320 | 0 | 0 | 1,080 | 1,640 |
| " 31...... | 110,880 | 0 | 200 | 0 | 80 | 0 | 400 | 640 |
| June 7...... | 301,200 | 0 | 400 | 0 | 0 | 0 | 2,600 | 4,000 |
| " 14...... | 181,800 | 0 | 200 | 0 | 200 | 0 | 800 | 4,400 |
| " 21...... | 80,600 | 0 | 0 | 0 | 0 | 0 | 0 | 400 |
| " 28...... | 35,100 | 0 | 0 | 0 | 0 | 0 | 0 | 200 |
| July 5...... | 3,840 | 0 | 0 | 0 | 0 | 0 | 0 | 120 |
| " 12...... | 1,200 | 0 | 0 | 0 | 0 | 0 | 0 | 180 |
| " 19...... | 12,800 | 0 | 0 | 0 | 40 | 0 | 40 | 240 |
| " 26...... | 13,040 | 0 | 0 | 0 | 120 | 0 | 120 | 300 |
| Aug. 2...... | 11,600 | 0 | 0 | 0 | 0 | 0 | 0 | 40 |
| " 9...... | 3,040 | 0 | 0 | 0 | 80 | 0 | 0 | 160 |
| " 16...... | 2,380 | 0 | 0 | 0 | 0 | 0 | 0 | 180 |
| " 23...... | 15,340 | 0 | 0 | 0 | 120 | 0 | 0 | 660 |
| " 30...... | 23,040 | 0 | 0 | 0 | 440 | 0 | 0 | 480 |
| Sept. 6...... | 8,360 | 0 | 40 | 0 | 80 | 0 | 0 | 0 |
| " 13...... | 20,800 | 0 | 0 | 0 | 120 | 0 | 0 | 240 |
| " 20...... | 20,320 | 0 | 0 | 0 | 120 | 0 | 60 | 360 |
| " 27...... | 98,200 | 100 | 700 | 0 | 300 | 0 | 200 | 700 |
| Oct. 4...... | 32,560 | 0 | 120 | 0 | 320 | 0 | 200 | 400 |
| " 11...... | 32,060 | 0 | 200 | 0 | 80 | 0 | 0 | 120 |
| " 18...... | 23,520 | 0 | 280 | 0 | 0 | 0 | 40 | 40 |
| " 25...... | 25,000 | 0 | 60 | 0 | 60 | 0 | 120 | 240 |
| Nov. 1...... | 8,480 | 0 | 120 | 0 | 0 | 0 | 0 | 60 |
| " 8...... | 15,080 | 0 | 0 | 0 | 0 | 0 | 0 | 120 |
| " 15...... | 13,000 | 200 | 0 | 200 | 0 | 0 | 0 | 0 |
| " 22...... | 10,880 | 480 | 0 | 80 | 0 | 0 | 0 | 160 |
| " 29...... | 6,100 | 80 | 0 | 4 | 0 | 0 | 0 | 0 |
| Dec. 6...... | 9,480 | 20 | 0 | 0 | 0 | 0 | 20 | 0 |
| " 13...... | 21,500 | 0 | 0 | 40 | 0 | 40 | 0 | 0 |
| " 20...... | 2,040 | 40 | 0 | 160 | 0 | 40 | 0 | 0 |
| " 27...... | 6,520 | 0 | 0 | 120 | 0 | 40 | 0 | 0 |
| Average...... | 40,609 | 78 | 113 | 373 | 49 | 2 | 124 | 539 |

## TABLE I—*continued.*

ORGANISMS PER CUBIC METER IN PLANKTON OF ILLINOIS RIVER IN 1908.

(An asterisk at head of column indicates that all entries in it are based on filter-paper collections.)

| 1898 | *Cyclops* young | Copepodan nauplii | *Diaptomus pallidus* | *Diaptomus siciloides* | *Hydra fusca* | Total Nematodes | Total Oligochætes | *Chironomus* larva |
|---|---|---|---|---|---|---|---|---|
| Jan. 11...... | 120 | 240 | 40 | 0 | 0 | 0 | 0 | 0 |
| " 21...... | 200 | 500 | 0 | 0 | 0 | 4,700 | 0 | 0 |
| " 25...... | 770 | 2,709 | 0 | 0 | 0 | 774 | 77 | 0 |
| Feb. 3...... | 72 | 72 | 0 | 0 | 0 | 24 | 100 | 0 |
| " 8...... | 80 | 80 | 0 | 0 | 0 | 80 | 0 | 0 |
| " 15...... | 160 | 800 | 0 | 0 | 0 | 400 | 0 | 0 |
| " 22...... | 126 | 3,159 | 0 | 0 | 0 | 0 | 126 | 0 |
| Mar. 1...... | 4 | 640 | 0 | 0 | 0 | 0 | 4 | 0 |
| " 8...... | 800 | 2,000 | 0 | 0 | 0 | 400 | 0 | 40 |
| " 15...... | 220 | 11,200 | 40 | 40 | 0 | 600 | 0 | 120 |
| " 22...... | 1,120 | 16,800 | 40 | 0 | 0 | 40 | 40 | 40 |
| " 29...... | 760 | 20,700 | 0 | 0 | 0 | 40 | 20 | 80 |
| Apr. 5...... | 1,420 | 32,300 | 20 | 0 | 0 | 0 | 40 | 80 |
| " 12...... | 1,100 | 25,100 | 60 | 0 | 0 | 40 | 40 | 160 |
| " 19...... | 5,500 | 27,200 | 0 | 0 | 0 | 100 | 100 | 300 |
| " 26...... | 24,320 | 20,800 | 0 | 0 | 0 | 320 | 0 | 300 |
| May 3...... | 19,600 | 182,400 | 0 | 0 | 0 | 0 | 0 | 400 |
| " 10...... | 53,200 | 169,600 | 0 | 0 | 0 | 0 | 200 | 400 |
| " 17...... | 27,900 | 166,400 | 0 | 0 | 900 | 4,800 | 200 | 700 |
| " 24...... | 12,160 | 126,400 | 0 | 0 | 840 | 40 | 80 | 280 |
| " 31...... | 5,680 | 103,800 | 0 | 0 | 160 | 40 | 80 | 440 |
| June 7...... | 23,800 | 270,400 | 0 | 0 | 0 | 0 | 200 | 200 |
| " 14...... | 11,400 | 164,800 | 0 | 0 | 0 | 200 | 0 | 0 |
| " 21...... | 14,600 | 65,600 | 0 | 0 | 0 | 0 | 0 | 400 |
| " 28...... | 4,500 | 30,400 | 0 | 0 | 0 | 300 | 100 | 400 |
| July 5...... | 1,320 | 2,400 | 0 | 0 | 0 | 0 | 40 | 480 |
| " 12...... | 780 | 180 | 0 | 60 | 0 | 0 | 180 | 300 |
| " 19...... | 1,680 | 10,800 | 0 | 60 | 0 | 0 | 80 | 480 |
| " 26...... | 840 | 11,600 | 0 | 0 | 0 | 0 | 0 | 120 |
| Aug. 2...... | 360 | 11,200 | 0 | 0 | 80 | 0 | 40 | 80 |
| " 9...... | 400 | 2,400 | 0 | 0 | 0 | 0 | 0 | 0 |
| " 16...... | 600 | 1,600 | 0 | 0 | 0 | 60 | 60 | 60 |
| " 23...... | 3,360 | 11,200 | 0 | 0 | 60 | 60 | 180 | 0 |
| " 30...... | 5,520 | 13,600 | 0 | 0 | 0 | 0 | 120 | 0 |
| Sept. 6...... | 240 | 8,000 | 0 | 0 | 0 | 40 | 160 | 80 |
| " 13...... | 4,320 | 16,000 | 60 | 0 | 0 | 120 | 180 | 0 |
| " 20...... | 0 | 19,000 | 0 | 60 | 0 | 120 | 60 | 60 |
| " 27...... | 0 | 96,000 | 0 | 200 | 0 | 300 | 400 | 200 |
| Oct. 4...... | 2,600 | 29,000 | 0 | 0 | 0 | 0 | 80 | 40 |
| " 11...... | 3,920 | 27,500 | 0 | 80 | 0 | 40 | 40 | 80 |
| " 18...... | 5,580 | 17,500 | 40 | 40 | 0 | 40 | 40 | 120 |
| " 25...... | 2,400 | 22,000 | 120 | 0 | 0 | 120 | 60 | 0 |
| Nov. 1...... | 300 | 8,000 | 0 | 0 | 0 | 0 | 180 | 0 |
| " 8...... | 960 | 14,000 | 0 | 0 | 0 | 120 | 120 | 0 |
| " 15...... | 400 | 12,000 | 100 | 0 | 0 | 100 | 100 | 0 |
| " 22...... | 160 | 10,000 | 0 | 0 | 0 | 2,000 | 320 | 0 |
| " 29...... | 4 | 6,000 | 12 | 0 | 0 | 0 | 120 | 0 |
| Dec. 6...... | 440 | 9,000 | 0 | 0 | 0 | 500 | 0 | 0 |
| " 13...... | 1,060 | 30,300 | 60 | 0 | 0 | 0 | 0 | 0 |
| " 20...... | 1,800 | 0 | 0 | 20 | 0 | 0 | 0 | 0 |
| " 27...... | 920 | 5,400 | 0 | 0 | 0 | 20 | 0 | 40 |
| Average...... | 4,780 | 36,707 | 11 | 10 | 39 | 318 | 76 | 124 |

## TABLE I—*concluded.*

### Organisms per Cubic Meter in Plankton of Illinois River in 1898.

(An asterisk at head of column indicates that all entries in it are based on filter-paper collections.)

| 1898 | Total *Corisa* | *Plumatella* statoblasts | Total Glochidia | Total Miscellaneous | Total Phytoplankton | Total Zoöplankton | Total Plankton |
|---|---|---|---|---|---|---|---|
| Jan. 11...... | 0 | 0 | 20 | 1,220 | 544,201,080 | 1,042,720 | 545,243,800 |
| " 21...... | 0 | 80 | 40 | 7,720 | 202,136,180 | 288,340 | 202,424,520 |
| " 25...... | 0 | 0 | 154 | 7,738 | 180,295,247 | 195,484 | 180,490,731 |
| Feb. 3...... | 0 | 0 | 24 | 648 | 619,030,830 | 1,381,960 | 620,412,790 |
| " 8...... | 0 | 0 | 80 | 2,160 | 297,341,760 | 651,200 | 279,992,960 |
| " 15...... | 0 | 0 | 0 | 6,000 | 653,122,000 | 1,091,920 | 654,213,920 |
| " 22...... | 0 | 0 | 0 | 3,285 | 115,514,812 | 715,697 | 116,230,509 |
| Mar. 1...... | 0 | 800 | 160 | 1,124 | 21,790,800 | 1,809,688 | 23,600,488 |
| " 8...... | 0 | 40 | 40 | 3,360 | 96,590,840 | 542,680 | 97,133,520 |
| " 15...... | 0 | 40 | 40 | 3,280 | 118,382,400 | 453,100 | 118,835,500 |
| " 22...... | 0 | 1,640 | 0 | 1,600 | 127,930,360 | 484,760 | 128,451,120 |
| " 29...... | 0 | 80 | 0 | 2,020 | 53,463,040 | 444,900 | 53,907,940 |
| Apr. 5...... | 0 | 900 | 100 | 1,860 | 42,470,860 | 363,980 | 42,834,834 |
| " 12...... | 0 | 220 | 20 | 980 | 90,934,320 | 1,432,400 | 102,366,720 |
| " 19...... | 0 | 400 | 0 | 3,100 | 927,956,220 | 2,134,800 | 930,091,020 |
| " 26...... | 0 | 320 | 0 | 20,160 | 3,872,537,280 | 16,092,840 | 3,848,630,120 |
| May 3...... | 0 | 0 | 0 | 10,800 | 3,200,166,960 | 898,919,800 | 4,099,086,760 |
| " 10...... | 0 | 0 | 200 | 13,600 | 4,467,165,760 | 42,826,200 | 4,509,991,960 |
| " 17...... | 0 | 100 | 0 | 213,900 | 2,148,960,400 | 31,091,900 | 2,180,052,300 |
| " 24...... | 0 | 1,200 | 0 | 5,360 | 190,671,160 | 4,969,580 | 195,640,740 |
| " 31...... | 120 | 100 | 0 | 4,720 | 252,704,250 | 2,772,200 | 255,476,450 |
| June 7...... | 200 | 0 | 0 | 24,000 | 259,129,000 | 9,695,000 | 268,824,000 |
| " 14...... | 0 | 0 | 0 | 4,400 | 1,149,333,480 | 10,959,400 | 1,160,292,880 |
| " 21...... | 300 | 0 | 0 | 3,300 | 641,056,900 | 15,159,600 | 656,216,500 |
| " 28...... | 200 | 0 | 300 | 10,900 | 612,686,240 | 7,796,700 | 620,482,940 |
| July 5...... | 40 | 0 | 120 | 5,800 | 257,668,840 | 495,337,320 | 753,000,160 |
| " 12...... | 120 | 60 | 120 | 5,320 | 223,936,060 | 4,135,160 | 228,071,220 |
| " 19...... | 40 | 80 | 0 | 2,680 | 1,578,635,720 | 1,717,240 | 1,580,352,960 |
| " 26...... | 0 | 60 | 0 | 1,440 | 281,604,120 | 907,240 | 282,511,360 |
| Aug. 2...... | 0 | 0 | 0 | 3,440 | 369,169,240 | 5,833,440 | 375,002,680 |
| " 9...... | 0 | 0 | 0 | 840 | 3,084,000,880 | 69,874,760 | 3,153,875,640 |
| " 16...... | 0 | 0 | 0 | 6,580 | 583,940,376 | 1,240,920 | 585,181,296 |
| " 23...... | 60 | 0 | 0 | 8,420 | 544,041,260 | 1,519,140 | 545,560,400 |
| " 30...... | 160 | 80 | 0 | 5,320 | 797,312,600 | 597,880 | 797,910,480 |
| Sept. 6...... | 0 | 0 | 0 | 4,320 | 488,146,040 | 60,463,480 | 548,609,520 |
| " 13...... | 60 | 60 | 0 | 2,420 | 676,773,060 | 1,712,720 | 678,485,780 |
| " 20...... | 180 | 0 | 0 | 5,920 | 330,837,120 | 32,466,660 | 363,303,780 |
| " 27...... | 0 | 0 | 0 | 12,100 | 511,099,300 | 3,201,200 | 514,300,500 |
| Oct. 4...... | 40 | 40 | 0 | 2,740 | 264,225,400 | 2,035,720 | 266,261,120 |
| " 11...... | 0 | 0 | 0 | 1,240 | 126,398,510 | 1,495,880 | 127,894,390 |
| " 18...... | 0 | 0 | 400 | 1,140 | 182,891,160 | 1,967,020 | 184,858,180 |
| " 25...... | 0 | 0 | 0 | 3,860 | 218,768,810 | 2,453,060 | 221,221,870 |
| Nov. 1...... | 0 | 120 | 60 | 4,360 | 209,418,675 | 1,189,380 | 210,608,055 |
| " 8...... | 0 | 0 | 0 | 15,300 | 277,953,180 | 1,281,220 | 279,234,400 |
| " 15...... | 0 | 0 | 100 | 7,500 | 407,573,600 | 732,300 | 408,305,900 |
| " 22...... | 400 | 0 | 0 | 25,680 | 466,411,780 | 1,109,040 | 467,520,820 |
| " 29...... | 0 | 80 | 240 | 1,900 | 364,032,900 | 799,980 | 364,832,880 |
| Dec. 6...... | 0 | 0 | 180 | 680 | 529,250,270 | 916,780 | 530,167,050 |
| " 13...... | 0 | 500 | 60 | 1,560 | 1,715,442,415 | 1,757,440 | 1,717,199,855 |
| " 20...... | 0 | 0 | 80 | 320 | 848,243,820 | 682,440 | 848,926,260 |
| " 27...... | 0 | 0 | 80 | 340 | 387,414,000 | 548,700 | 387,926,700 |
| Average...... | 37 | 135 | 52 | 9,393 | 723,283,871 | 34,226,468 | 756,548,801 |

# BIBLIOGRAPHY.


Amberg, C.

'00. Beiträge zur Biologie des Katzensees. Inaug. Diss. 78 pp., 5 Taf. Zurich. Also in Vierteljahrsschr. d. naturf. Ges. Zurich, Jahrg. 45, pp. 59–136.

Asper, G., und Heuscher, J.

'85. Zur Naturgeschichte der Alpenseen. Jahresber. St. Gall. Naturwiss. Ges., 1885–86. 43 pp.

Apstein, C.

'96. Das Süsswasserplankton. Methode und Resultate der quantitativen Untersuchung. Mit 113 Abbildungen. 200 pp., 5 Tab. Kiel und Leipzig.

Bertram, [A.]

'92. Beiträge zur Kenntniss der Sarcosporidien nebst einem Anhange über parasitische Schläuche in der Leibeshöhle von Rotatorien. Zool. Jahrb., Abth. f. Anat. u. Ont., Bd. V., pp. 581–604.

Birge, E. A.

'91. List of Crustacea Cladocera from Madison, Wisconsin. Trans. Wis. Acad., Vol. VIII., pp. 379–398, Pl. 13.

'94. A Report on a Collection of Cladocera, mostly from Lake St. Clair, Michigan. Bull. Mich. Fish Comm., No. 4, pp. 45–49. 1 table.

'95. Plankton Studies on Lake Mendota. I. The Vertical Distribution of the Pelagic Crustacea during July, 1894. Trans. Wis. Acad. Sci., Arts, and Letters, Vol. X., pp. 421–484, Pl. VII.–X.

'97. Plankton Studies on Lake Mendota. II. The Crustacea of the Plankton from July, 1894, to December, 1896. Trans. Wis. Acad. Sci., Arts, and Letters, Vol. XI., pp. 274–448, Pl. XV.–XLII.

Borge, O.

'00. Schwedisches Süsswasserplankton. Botaniska Notiser, 1900, pp. 1–26, Taf. 1.

Brewer, A. D.

'98. A Study of the Copepoda found in the Vicinity of Lincoln, Nebraska. Journ. Cin. Soc. Nat. Hist., Vol. XIX., pp. 119–138, Pl. VII.

Brunnthaler, Josef.

'00. Plankton-Studien. I. Das Phytoplankton des Donaustromes bei Wien. Verhandl. d. k. k. zool.-botan. Ges. Wien, Jahrg. 1900, Bd. L., pp. 308–311.

'01. Die Coloniebildenden *Dinobryon*-Arten. (Subgenus *Eudinobryon* Lauterborn.) Verhandl. d. k. k. zool.-botan. Ges. Wien, Jahrg. 1901, Bd. LI., pp. 293–306. Mit 5 Fig. im Text.

Bütschli, O.

'80–'89. Protozoa. Bronn's Klassen und Ordnungen des Thierreich, Bd. I., Abth. I.–III. 2035 pp., 79 Taf. Leipzig und Heidelberg.

Burckhardt, G.

'00. Faunistische und systematische Studien über das Zooplankton der grösseren Seen der Schweiz und ihrer Grenzgebiete. Rev. Suisse de Zoologie, T. VII., pp. 353–713, Pl. 19–22.

'00a. Quantitative Studien über das Zooplankton des Vierwaldstättersees. Mitteil. d. naturf. Ges. Luzern, 1900, Heft 3, pp. 129–439; Separatabdruck, 311 pp.

Burrill, T. J.

'02. Report of the University of Illinois. Report of Streams Examination, Chemic and Bacteriologic, of the water between Lake Michigan at Chicago and the Mississippi River at St. Louis, * * * published by authority of the Trustees of the Sanitary District of Chicago, pp. 97–119, Pl. XXI.–XXX. (in text), Tab. 1–80.

'04. River Pollution and Purification: A Study of the Effect of Chicago Sewage upon the Water Supply of St. Louis. Trans. Am. Micr. Soc., Vol. XXV., pp. 105–120, Tab. I., Pl. XV.–XVII.

Calkins, G. N.

'02. Studies on the Life-History of Protozoa. I. The Life-Cycle of *Paramœcium caudatum*. Arch. f. Entwicklungsmechanik d. Org., Bd. XV., pp. 139–186. 4 fig. in text.

Caullery, M., et Mesnil, F.
'04. Sur les affinités des Actinomyxidies. Compt. Rend. Soc. Biol. Paris, T. 56, pp. 410–412.

Cohn, Ludwig.
'03. Untersuchungen über des Plankton des Löwentin und einiger anderer Seen Masurens. Zeitschr. f. Fischerei, Bd. X., pp. 201–331, Taf. 1–12.

Daday, E. v.
'85. Neue Thierarten aus der Süsswasserfauna von Budapest. Természetr. Füzetek, Vol. IX., pp. 208–215, Taf. XI.

Forbes, S. A.
'78. The Food of Illinois Fishes. Bull. Ill. State Lab. Nat. Hist., Vol. I., No. 2, pp. 71–89.
'80. On the Food of Young Fishes. Bull. Ill. State Lab. Nat. Hist., Vol. I., No. 3, pp. 66–79; 2d ed., 1903, pp. 71–85.
'82. On some Entomostraca of Lake Michigan and Adjacent Waters. Am. Nat., Vol. XVI., pp. 537–542, 640–650, Pl. VIII., IX.
'83. The first Food of the Common Whitefish (*Coregonus clupeiformis* Mitch.). Bull. Ill. State Lab. Nat. Hist., Vol. I., No. 6, pp. 95–109.
'90. On some Lake Superior Entomostraca. Rep. U. S. Comm. Fish and Fisheries, 1887, pp. 701–718, Pl. I.–IV.
'93. A Preliminary Report on the Aquatic Invertebrate Fauna of the Yellowstone National Park, Wyoming, and the Flathead Region of Montana. Bull. U. S. Fish Comm., Vol. XI., pp. 207–258, Pl. XXXVII.–XLII.

Forbes, E. B.
'97. A Contribution to a Knowledge of North American Fresh-water Cyclopidæ. Bull. Ill. State Lab. Nat. Hist., Vol. V., pp. 27–82, Pl. VIII.–XX.

Fordyce, C.
'00. The Cladocera of Nebraska. Trans. Am. Micr. Soc., Vol. XXII., pp. 119–174. 4 pl. Also, in 1901, in Studies from the Zool. Lab. Univ. Nebr., No. 42, Pl. XXII.–XXV.

Frič, A., und Vávra, V.
'01. Untersuchungen über die Fauna der Gewässer Böhmens. V. Untersuchung des Elbeflusses und seiner Altwässer. Arch. der Naturwiss. Landesdurchforsch. v. Böhmen, Bd. XI., No. 3, pp. 1–156. Mit 119 Abb. im Text.

Friedländer, B.

'01. Herrn Alfred Goldsborough Mayer's Entdeckung eines "Atlantischen Palolo" und deren Bedeutung für die Frage nach unbekannten Kosmischen Einflüssen auf biologische Vorgänge. Zugleich eine Beleuchtung der darwinistischen Betrachtungsweise. Biol. Centralbl., Bd. XXI., pp. 312–317, 352–366.

Fuhrmann, O.

'00. Beitrag zur Biologie des Neuenburger Sees. Biol. Centralbl., Bd. XX., pp. 85–96, 120–128. 1 Fig.

Garbini, A.

'98. Due nuovi Rizopodi limnetici (*Difflugia cyclotellina* — *Heterophrys Pavesii*). Zool. Anz., Bd. XXI., pp. 667–670. 2 Fig.

Haeckel, E.

'90. Plankton Studien. Jenaische Zeitschr., Bd. XXV., pp. 232–336.

Hart, C. A.

'95. On the Entomology of the Illinois River and Adjacent Waters. Bull. Ill. State Lab. Nat. Hist., Vol. IV., pp. 149–273, Pl. I.–XV.

Hempel, A.

'96. Descriptions of New Species of Rotifera and Protozoa from the Illinois River and Adjacent Waters. Bull. Ill. State Lab. Nat. Hist., Vol. IV., pp. 310–317, Pl. XXII.–XXVI.

'99. A List of the Protozoa and Rotifera found in the Illinois River and Adjacent Lakes at Havana, Ill. Bull. Ill. State Lab. Nat. Hist., Vol. V., pp. 301–388. 5 fig.

Hensen, V.

'87. Ueber die Bestimmung des Plankton's oder des im Meere treibenden Materials an Pflanzen und Thieren. Fünft. Ber. d. Komm. zu wiss. Untersuch. d. deutsch. Meere in Kiel, pp. 1–107 + I.–XVIII. 6 Tab.

Herrick, C. L.

'84. A Final Report on the Crustacea of Minnesota included in the Orders Cladocera and Copepoda. Twelfth Ann. Rep. Geol. and Nat. Hist. Surv. Minn., pp. 1–191, Pl. A–V.

Herrick, C. L., and Turner, C. H.

'95. Synopsis of the Entomostraca of Minnesota. Geol. and Nat. Hist. Surv. Minn., Zool. Series, II. 337 pp. and 81 pl.

Heuscher, J.

'85. (See Asper, G., und Heuscher, J.)

Huitfeldt-Kaas, H.

'98. Plankton in norwegischen Binnenseen. Biol. Centralbl., Bd. XVIII., pp. 625–636. 2 Fig.

Jennings, H. S.

'94. The Rotatoria of the Great Lakes and of some of the Inland Lakes of Michigan. Bull. Mich. Fish Comm., No. 3, pp. 1–34, Pl. 1 and 2.

'96. Report on the Rotatoria. Bull. Mich. Fish Comm., No. 6, pp. 85–93, Fig. 1 and 2.

'00. Rotatoria of the United States, with especial Reference to those of the Great Lakes. Bull. U. S. Fish Comm., Vol. XIX., pp. 67–104, Pl. 14–22.

'00a. A Report of Work on the Protozoa of Lake Erie with especial Reference to the Laws of their Movements. Bull. U. S. Fish Comm., Vol. XIX., pp. 105–114.

Jordan, E. O.

'00. Some Observations on the Bacterial Self-Purification of Streams. Journ. Exper. Med., Vol. V., pp. 271–314, Pl. XX.

Kellicott, D. S.

'88. Partial List of Rotifera of Shiawassee River at Corunna, Michigan. Proc. Am. Soc. Microscopists, Vol. X., pp. 84–96. 3 fig.

'97. The Rotifera of Sandusky Bay (Second Paper). Proc. Am. Micr. Soc., Vol. XIX., pp. 43–54.

Kelly, H. M.

'99. A Statistical Study of the Parasites of the Unionidæ. Bull. Ill. State Lab. Nat. Hist., Vol. V., pp. 399–418.

Kertész, K.

'94. Budapest és Környékének Rotatoria-faunája [The Rotifer fauna of Budapest and Neighborhood]. Inaug. Diss. 55 pp., 1 pl. Budapest, 1894.

Knauthe, K.

'98. Der Kreislauf der Gase in unseren Gewässern. Biol. Centralbl., Bd. XVIII., pp. 785–805.

Kofoid, C. A.

'95. A Report on the Protozoa observed in Lake Michigan and the Inland Lakes in the Neighborhood of Charlevoix during the Summer of 1894. Bull. Mich. Fish Comm., No. 6, pp. 76–84.

'97. Plankton Studies. I. Methods and Apparatus in Use in Plankton Investigations at the Biological Experiment Station of the University of Illinois. Bull. Ill. State Lab. Nat. Hist., Vol. V., pp. 1–25, Pl. I.–VII.

'03. Plankton Studies. IV. The Plankton of the Illinois River, 1894–1899, with Introductory Notes on the Hydrography of the Illinois River and its Basin. Part I. Quantitative Investigations and General Results. Bull. Ill. State Lab. Nat. Hist., Vol. VI., pp. vi–xviii, 95–629. 5 text fig. and 50 pl.

Krämer, Aug.

'97. Ueber den Bau der Korallenriffe und die Planktonvertheilung an den Samoanischer Küsten. Mit Anhang: Ueber den Palolowurm, von Dr. A. Collin. 174 pp., 1 Karte. Kiel und Leipzig.

Lauterborn, R.

'93. Ueber Periodicität in Auftreten und in der Fortpflanzung einiger pelagischer Organismen des Rheins und seiner Altwasser. Verhandl. d. Naturhist.-Med. Vereins Heidelberg, N. F., Bd. V., pp. 103–124.

'93a. Beiträge zur Rotatorienfauna des Rheins und seiner Altwasser. Zool. Jahrb., Abth. f. Syst., Geogr., u. Biol. d. Thiere, Bd. VII., pp. 254–273, Taf. 11.

'94. Ueber die Winterfauna einiger Gewässer der Oberrheinebene. Mit Beschreibungen neuer Protozoën. Biol. Centralbl., Bd. XIV., pp. 390–398.

'98. Vorläufige Mittheilung über den Variationskreis von *Anuræa cochlearis* Gosse. Zool. Anz., Bd. XXI., pp. 597–604.

'98a. Ueber die zyklische Fortpflanzung limnetischer Rotatorien. Biol. Centralbl., Bd. XVIII., pp. 173–183.

Leger, L.

'04. Considérations sur le genre Triactinomyxon et les Actinomyxidies. Compt. Rend. Soc. Biol. Paris, T. 56, pp. 846–848.

Leidy, Joseph.

'79. Fresh-Water Rhizopods of North America. Rep. U. S. Geol. Surv. Terr., Vol. XII. 324 pp., 48 pl.

'87. *Asplanchna ebbesbornii*. Proc. Acad. Nat. Sci. Phila., 1887, p. 157.

Lemmermann, E.

'00. Beiträge zur Kenntniss der Planktonalgen. XI. Die Gattung Dinobryon Ehrenb. Ber. d. deutsch. Bot. Ges., Bd. XVIII., pp. 500–524, Taf. XVIII., XIX.

Levander, K. M.

'94. Kleine Beiträge zur Kenntniss des Thierlebens unter dicker Eisdecke in einiger Gewässern Finlands. Meddel. Soc. pro Fauna et Flora Fennica, Bd. XX., pp. 66–71.

'00. Zur Kenntniss der Fauna und Flora finnischer Binnenseen. Acta Soc. pro Fauna et Flora Fennica, Vol. XIX., No. 2, pp. 1–55. 1 Fig.

Marsh, C. Dwight.

'93. On the Cyclopidæ and Calanidæ of Central Wisconsin. Trans. Wis. Acad. Sci., Arts, and Letters, Vol. IX., pp. 189–224, Pl. III.–VI.

'95. On the Cyclopidæ and Calanidæ of Lake St. Clair, Lake Michigan, and certain of the Inland Lakes of Michigan. Bull. Mich. Fish Comm., No. 5. 24 pp., 5 pl.

'97. On the Limnetic Crustacea of Green Lake. Trans. Wis. Acad. Sci., Arts, and Letters, Vol. XI., pp. 179–224, Pl. V.–XIV.

Marsson, M.

'00. Zur Kenntnis der Planktonverhältnisse einiger Gewässer der Umgebung von Berlin. Forschungsber. aus der Biol. Station zu Plön, Teil 8, pp. 86–119.

Maskell, W. M.

'87. On the Fresh-water Infusoria of the Wellington District. Trans. New Zealand Inst., Vol. XIX., pp. 49–61, Pl. III.–V.

Maupas, E.

'88. Recherches expérimentales sur la multiplication des Infusoires ciliés. Arch. de Zool. Expér. (2), T. VI., pp. 165–277. 4 pl.

Mayer, A. G.

'00. An Atlantic "Palolo," *Staurocephalus gregaricus*. Bull. Mus. Comp. Zool., Vol. XXXVI., pp. 1–14, Pl. I.–III.

Meissner, V.

'02. Notiz über niedere Crustaceen des Wolga-Flusses bei Saratow. Zool. Anz., Bd. XXVI., pp. 51–55.

'03. Contribution to the Fauna of the lower Crustacea of the River Volga. Year-book of the Volga Biol. Station, 1903. 43 pp., 2 tab., Pl. II.–IV. (Russian.)

Minkiewitsch, R.

'98. Some Observations on the Protozoa, made at the Biological Station at Bologoé. Rep. Imp. Soc. Nat. St. Petersburg, Vol. XXIX., pp. 239–246, 267–269.

Mrazek, A.

'00. [Review of Štolc, '99.] Zool. Centralbl., Bd. VII., pp. 594–595. Mit 2 Fig. im Text.

Needham, J. G., and Hart, C. A.

'01. The Dragon-flies (Odonata) of Illinois, with Descriptions of the Immature Stages. Part I. Petaluridæ, Æschnidæ, and Gomphidæ. Bull. Ill. State Lab. Nat. Hist., Vol. VI., pp. 1–94, Pl. I.

Ostwald, Wolfgang.

'03. Theoretische Planktonstudien. Zool. Jahrb., Abth. f. Syst., Geogr., u. Biol. d. Thiere, Bd. XVIII., pp. 1–62. Mit 4 Curven und 2 Abb. im Text.

'03a. Ueber eine neue theoretische Betrachtungsweise in der Planktologie. Forschungsber. a. d. Biol. Station zu Plön, Teil X., pp. 1–49.

Penard, E.

'02. Faune Rhizopodique du Bassin du Léman. Avec nombreuses figures dans le texte. 714 pp. Genève.

Plate, Ludwig.

'85. Beiträge zur Naturgeschichte der Rotatorien. Jenaische Zeitschr., Bd. XIX., pp. 1–120, Taf. I.–III.

Prowazek, S.

'00. *Synedra hyalina*, eine apochlorotische Bacillarie. Oesterr. botan. Zeitschr., Bd. 50, pp. 69–73. 2 Fig.

Przesmycki, A. M.

'01. Ueber parasitische Protozoen aus dem Inneren der Rotatorien. Anz. Akad. Wiss. Krakow, 1901, pp. 358–408. 3 Taf.

Ross, L. S.

'97. A New Species of Daphnia, and Brief Notes on other Cladocera of Iowa. Proc. Iowa Acad. Sci., Vol. IV., pp. 162–166. 1 fig.

Rossinski, D. M.

'92. Materialien zur Kenntniss der Evertebratenfauna des Moskwaflusses. Bull. Soc. Hist. Nat., Anthrop., Ethnogr., T. LXVII., Suppl. à Nr. 6, pp. 1–38.

Rousselet, C. F.

'97. *Brachionus Bakeri* and its Varieties. Journ. Quekett Micr. Club., Ser. II., Vol. VI., pp. 328–332, Pl. XVI.

'02. Third List of New Rotifers since 1889. Journ. R. Micr. Soc., 1902, pp. 148–154.

'02a. The Genus Synchæta: A Monographic Study with Descriptions of five New Species. Journ. R. Micr. Soc., 1902, pp. 269–290, 393–411, Pl. III.–VIII.

Roux, J.

'99. Observations sur quelques Infusoires Ciliés des Environs de Genève, avec la description de nouvelles espèces. Rev. Suisse de Zool., T. 6, pp. 555–636, Pl. XIII, XIV.

'01. Faune Infusorienne des Eaux stagnantes des Environs de Genève. Mém. Inst. Nat. Genève, T. XIX. 148 pp., 8 pl.

Sand, R.

'01. Étude monographique sur le groupe des Infusoires Tentaculifères. 441 pp., 24 pl. Bruxelles, 1901. Published also in Ann. de la Soc. Belge de Micr., T. XXIV., pp. 57–189; T. XXV., pp. 7–205; T. XXVI., pp. 11–119.

Say, T.

'18. An Account of the Crustacea of the United States. Journ. Acad. Nat. Sci. Phila., Vol. I., pp. 423–458.

Schacht, F. W.

'97. The North American Species of Diaptomus. Bull. Ill. State Lab. Nat. Hist., Vol. V., pp. 97–207, Pl. XXI.–XXXV.

'98. The North American Centropagidæ belonging to the Genera Osphranticum, Limnocalanus, and Epischura. Bull. Ill. State Lab. Nat. Hist., Vol. V., pp. 225–269.

Schewiakoff, Wl.

'93. Über die geographische Verbreitung der Süsswasser-Protozoen. Mém. l'Acad. Imper. des Sci. de St.-Petersbourg, Ser. VII., T. XLI., No. 8. 201 pp., 4 Taf.

Schorler, B.

'00. Das Plankton der Elbe bei Dresden. Zeitschr. f. Gewässerkunde, Bd. III., pp. 1–27.

Schröder, B.

'97. Attheya, Rhizosolenia und andere Planktonorganismen in Teiche des botanischen Gartens zu Breslau. Ber. d. deutsch. botan. Ges., Bd. XV., pp. 367–374, Taf. XVII.

'97a. Ueber das Plankton der Oder. Ber. d. deutsch. botan. Ges., Bd. XV., pp. 482–492, Taf. XXV.

Scott, Thomas.

'99. The Invertebrate Fauna of the Inland Waters of Scotland. Report on Special Investigation. Ann. Rep. Fish. Board Scotland, Vol. XVII., pp. 132–204, Pl. VII.

Scourfield, D. J.

'98. The Entomostraca of Epping Forest, with some General Remarks on the Group. Essex Naturalist, Vol. X., pp. 193–210, 259–274, 313–334.

Seligo, A.

'00. Untersuchungen in den Stuhmer Seen. Nebst einem Anhange: Das Pflanzenplankton preussischer Seen, von B. Schröder. 88 pp., 9 Tab., und 10 Taf. Danzig.

Sharpe, R. W.

'97. Contribution to a Knowledge of the North American Freshwater Ostracoda included in the Families Cytheridæ and Cyprididæ. Bull. Ill. State Lab. Nat. Hist., Vol. IV., pp. 414–482, Pl. XXXIX.–XLVIII.

Skorikow, A. S.

'96. Rotifera of the Neighborhood of Charkow. Contrib. Soc. Nat. Imp. Univ. Charkow, Vol. XXX., pp. 209–374, Pl. VI.–IX. (Russian.)

'97. Contribution to an Investigation of the Distribution of the Invertebrates of the River Udy. Contrib. Soc. Nat. Imp. Univ. Charkow, Vol. XXXI., pp. 39–48. (Russian.)

'02. Die Erforschung des Potamoplanktons in Russland. Biol. Centralbl., Bd. XXII., pp. 551–570.

Smith, F.

'94. List of the Protozoa and Mollusca observed in Lake St. Clair in the Summer of 1893. Bull. Mich. Fish Comm., No. 4, pp. 42–44.

'00. Notes on Species of North American Oligochæta. III. List of Species found in Illinois, and Descriptions of Illinois Tubificidæ. Bull. Ill. State Lab. Nat. Hist., Vol. V., pp. 441–458, Pl. XXXIX., XL.

Smith, S. I.

'74. Sketch of the Invertebrate Fauna of Lake Superior. Rep. U. S. Fish Comm., 1872–73, Part II., pp. 690–707.

Sowinski, W. K.

'88. Beschreibung der Fauna der Süsswassercrustaceen aus der Umgebung Kiews und des nördlichen Teiles des Gouvernement Kiew. Schriften der Kiew'schen-Naturf. Ges., 1888, Bd. IX., pp. 225–298. Mit Karte.

Stenroos, K. E.

'97. Zur Kenntnis der Crustaceen-Fauna von Russisch-Karelien. Cladocera, Calanidæ. Acta Soc. pro Fauna et Flora Fennica, Bd. XV., No. 2. 72 pp. Mit einer Tafel und einer Karte.

'98. Das Thierleben im Nurmijärvi-See. Acta Soc. pro Fauna et Flora Fennica, Bd. XVII., pp. 1–259, Taf. I–III. 1 Karte.

Steuer, Adolf.

'01. Die Entomostrakenfauna der "alten Donau" bei Wien. Eine ethologische Studie. Mit einem Anhang: Zur Frage über Ursprung und Verbreitung der Entomostrakenfauna des Süsswassers. Zool. Jahrb., Abth. f. Syst., Geogr., u. Biol. d. Thiere, Bd. XV., pp. 1–156, Taf. I.–XII. Mit 20 Abb. im Text.

Stingelin, Th.

'97. Ueber jahreszeitliche, individuelle und locale Variation bei Crustaceen, nebst einigen Bemerkungen über die Fortpflanzung bei Daphniden und Lynceiden. Forschungsber. a. d. Biol. Station zu Plön, Th. V., pp. 150–165. Mit 5 Fig. im Text.

Stokes, A. C.

'86–'88. A Preliminary Contribution toward a History of the Fresh-water Infusoria of the United States. Journ. Trenton Nat. Hist. Soc., Vol. I., pp. 71–319, Pl. I.–XIII.

'94. Notices of presumably undescribed Infusoria. Proc. Am. Phil. Soc., Vol. XXXIII., p. 338–345, Pl. XXI.

Štolc, A.

'99. Actinomyxidia, novà Mesozoů, příbuzná Myxosporidiím. Rozp. Česke Ak. Cís. Frant. Jos. II., VIII., 22. 12 pp., 3 pl.

Thorpe, V. G.

'93. The Rotifera of China. Journ. R. Micr. Soc., 1893, pp. 145–152. 2 pl.

Verworn, M.

'97. Die polare Erregung der lebendigen Substanz durch den constanten Strom. Archiv f. Physiologie (Pflüger), Bd. 65, pp. 63–81, Taf. IV.

Volk, R.

'03. Hamburgische Elb-Untersuchung. I. Allgemeines über die biologischen Verhältnisse der Elbe bei Hamburg und über die Einwirkung der Sielwässer auf die Organismen des Stromes. Mitth. a. d. Naturhist. Mus. in Hamburg, Bd. XIX., pp. 65–164, Taf. I.–VII.

Ward, H. B.

'96. A Biological Examination of Lake Michigan in the Traverse Bay Region. Bull. Mich. Fish Comm., No. 6. 100 pp., 5 pl.

Weber, E. F.

'98. Faune Rotatorienne du Bassin du Léman (2me partie). Rev. Suisse de Zool., T. V., pp. 355–785, Pl. 16–25.

Weismann, A.

'79. Beiträge zur Naturgeschichte der Daphnoiden. VI. Samen und Begattung der Daphnoiden. VII. Die Enstehung der cyclischen Fortpflanzung bei den Daphnoiden. Zeitschr. f. wiss. Zool., Bd. XXXIII., pp. 55–270, Taf. VIII.–XIII.

Wesenberg-Lund, C.

'98. Über dänische Rotiferen und über die Fortpflanzungsverhältnisse der Rotiferen. Zool. Anz., Bd. XXI., pp. 200–211.

'00. Von dem Abhängigkeitsverhältnis zwischen dem Bau der Planktonorganismen und dem spezifischen Gewicht des Süsswassers. Biol. Centralbl., Bd. XX., Nr. 18 und 19, pp. 606–619, 644–656.

Whipple, G. C.

'94. Some Observations on the Growth of Diatoms in Surface Waters. Tech. Quart., Vol. VII., pp. 214–231.

Whipple, G. C., and Jackson, D. D.

'99. Asterionella, its Biology, its Chemistry, and its Effect on Water Supplies. Journ. N. E. Waterworks Ass'n, Vol. XIV., pp. 1–25. 4 pl.

Woodworth, W. McM.

'97. On some Turbellaria from Illinois. Bull. Mus. Comp. Zool., Vol. XXXI., pp. 1–16. 1 pl.

Zacharias, O.

'94. Faunistische Mittheilungen. Forschungsber. a. d. Biol. Station zu Plön, Th. II., pp. 57–90, Taf. I., II. Mit 2 Fig. im Text.

'97. Neue Beiträge zur Kenntniss des Süsswasserplanktons. Forschungsber. a. d. Biol. Station zu Plön, Th. V., pp. 1–9, Taf. I.

'97a. Die Fauna der Versuchsteiche. Zeit. f. Fischerei, Bd. V., pp. 37–51.

'98. Das Heleoplankton. Zool. Anz., Bd. XXI., pp. 24–32.

'98a. Das Potamoplankton. Zool. Anz., Bd. XXI., pp. 41–48.

'98b. Untersuchungen über das Plankton der Teichgewässer. Forschungsber. a. d. Biol. Station zu Plön, Teil VI., pp. 89–139, Taf. IV.

'00. *Trichodina pediculus* Ehrb. als Mitglied des Planktons der Binnenseen. Biol. Centralbl., Bd. XX., p. 463.

Zernow, S. A.

'01. Remarks on the Zooplankton of the Rivers Schoschma and Wjätka (Region Malmyz, Government Wjätka). Bull. Imp. Soc. Friends Sci. Moscow, Zool. Section, Vol. 3, pp. 28–35, 36. 1 pl.

Zimmer, C., und Schröder, B.
'99. Das Plankton des Oderstromes. Forschungsber. a. d. Biol. Station zu Plön, Teil VII., pp. 1–24.

Zumstein, H.
'99. Zur Morphologie und Physiologie der *Euglena gracilis* Klebs. Inaug. Diss. 50 pp., 1 Taf. Leipzig. Also, in 1900, in Jahrb. f. wiss. Botanik, Bd. XXXIV., pp. 149–198, Taf. VI.

Zykoff, W.
'00. Das Potamoplankton der Wolga bei Saratow. Zool. Anz., Bd. XXIII., pp. 625–627.
'03. Report on the Fauna of the Volga and the Aquatic Fauna of the Government of Saratoff. Bull. Soc. Naturalists of Moscow, 1903, pp. 1–148, Pl. I., II. (Russian.)

# EXPLANATION OF PLATES.

## PLATE I.

Seasonal distribution of synthetic groups of planktonts, *Chlorophyceæ*, *Bacillariaceæ*, and *Mastigophora*, from July 1, 1895, to October 1, 1896. Note changes of scale indicated at bottom of diagram. Numbers in column at left apply only to 1895. In this plate and in II. and IV., apices exceeding the limit of the diagram are dropped down between dotted lines to show location. Circles at bottom indicate location of day of full moon.

## PLATE II.

The same as above, from July 1, 1897, to April 1, 1899. Note change in scale from previous plate.

## PLATE III.

Seasonal distribution of total *Rotifera* and *Crustacea* from July 1, 1895, to October 1, 1896. The *Crustacea* included, belong almost exclusively to the *Entomostraca*. Apices exceeding the limits of the diagram are dropped down between dotted lines to show location. Totals include both adult and immature stages of the *Entomostraca* when detached from parent, and both free and attached eggs of the *Rotifera*.

## PLATE IV.

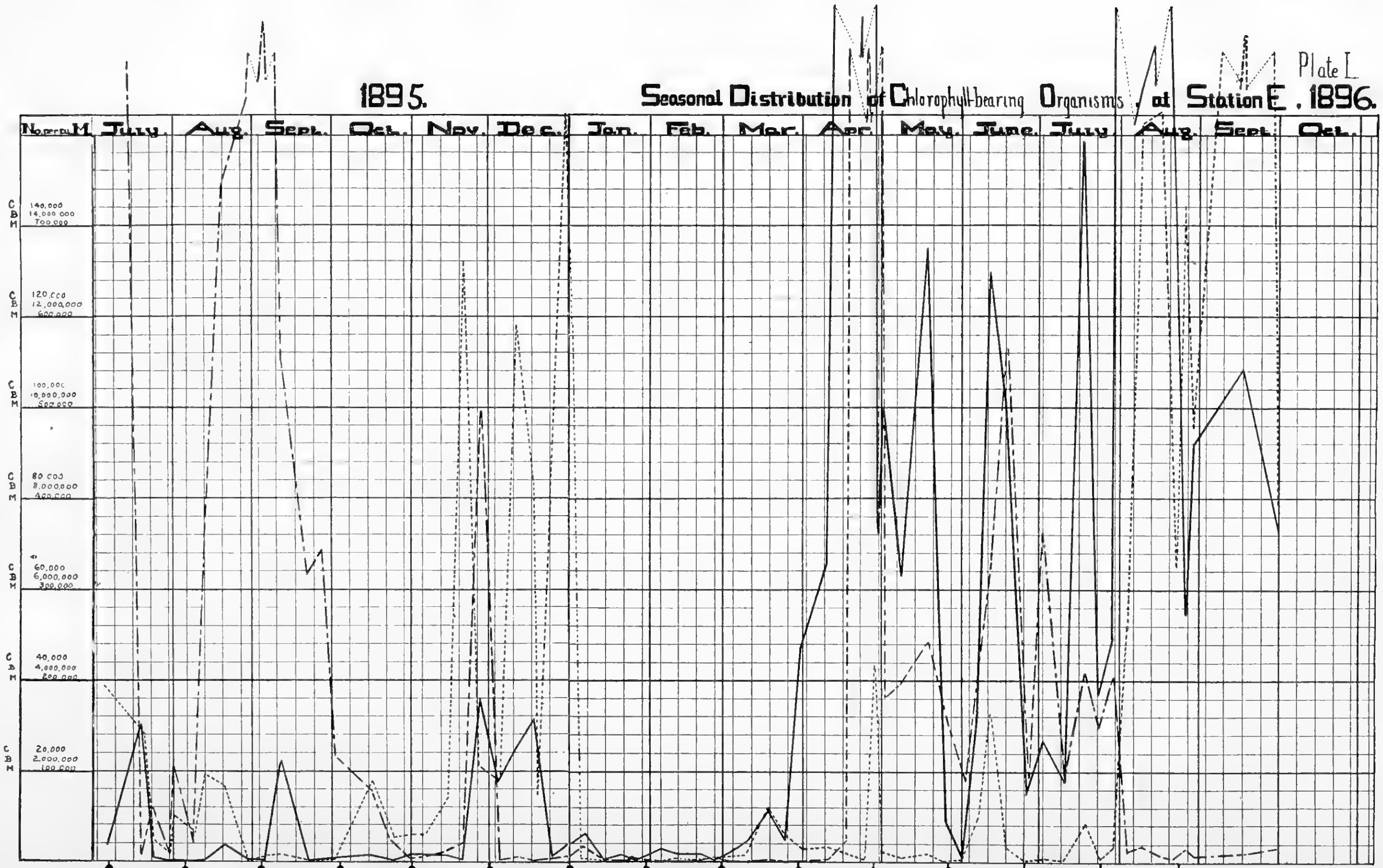
The same as above, from July 1, 1897, to April 1, 1899.

## PLATE V.

Seasonal distribution of *Polyarthra platyptera*. Total number of individuals, not including eggs, represented by ordinants, parts of which exceeding 200,000 are represented by diagonal lines instead of solid vertical lines. Thus parts of a seasonal plot which overlap those above it on the plate are represented by the diagonally-lined ordinants.

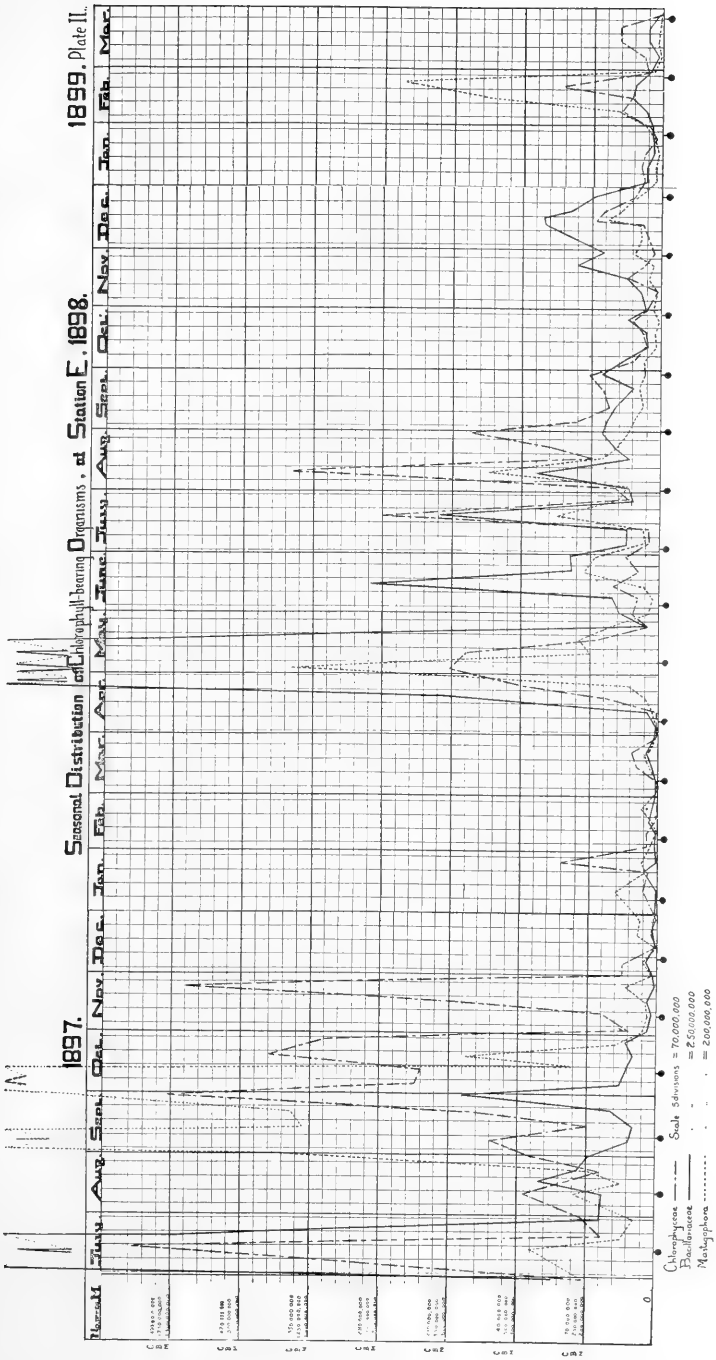
Plate I.

# 1895. Seasonal Distribution of Chlorophyll-bearing Organisms at Station E. 1896.




1895 { Chlorophyceae ——— Scale—5 divisions = 20,000.
Bacillariaceae ——— " " " = 2,000,000.
Mastigophora ......... " " " = 100,000

1896 { Chlorophyceae ——— Scale—5 divisions = 20,000 : changes, Aug 1, to 5 divisions = 70,000,000
Bacillariaceae ——— " " " = 2,000,000
Mastigophora ------ " " " = 5,000,000



Seasonal Distribution of Chlorophyll-bearing Organisms, at Station E, 1898.
1899. Plate II.
1897.
1898.
July. Aug. Sept. Oct. Nov. Dec. Jan. Feb. Mar. Apr. May. June. July. Aug. Sept. Oct. Nov. Dec. Jan. Feb. Mar.
Chlorophyceae —·—·— Scale 5 divisions = 70,000,000
Bacillariaceae ——— " " = 250,000,000
Mastigophora ········ " " = 200,000,000

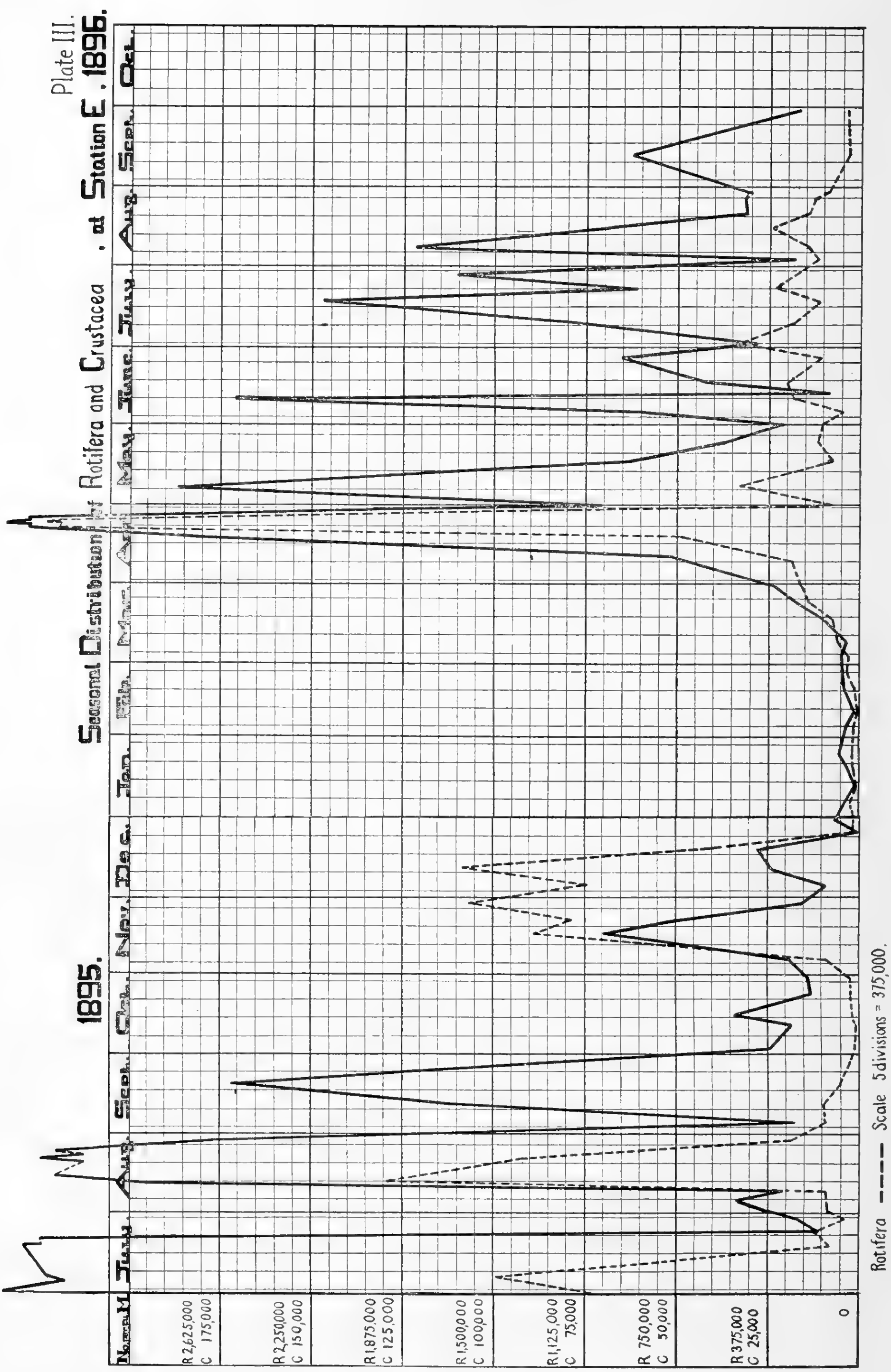
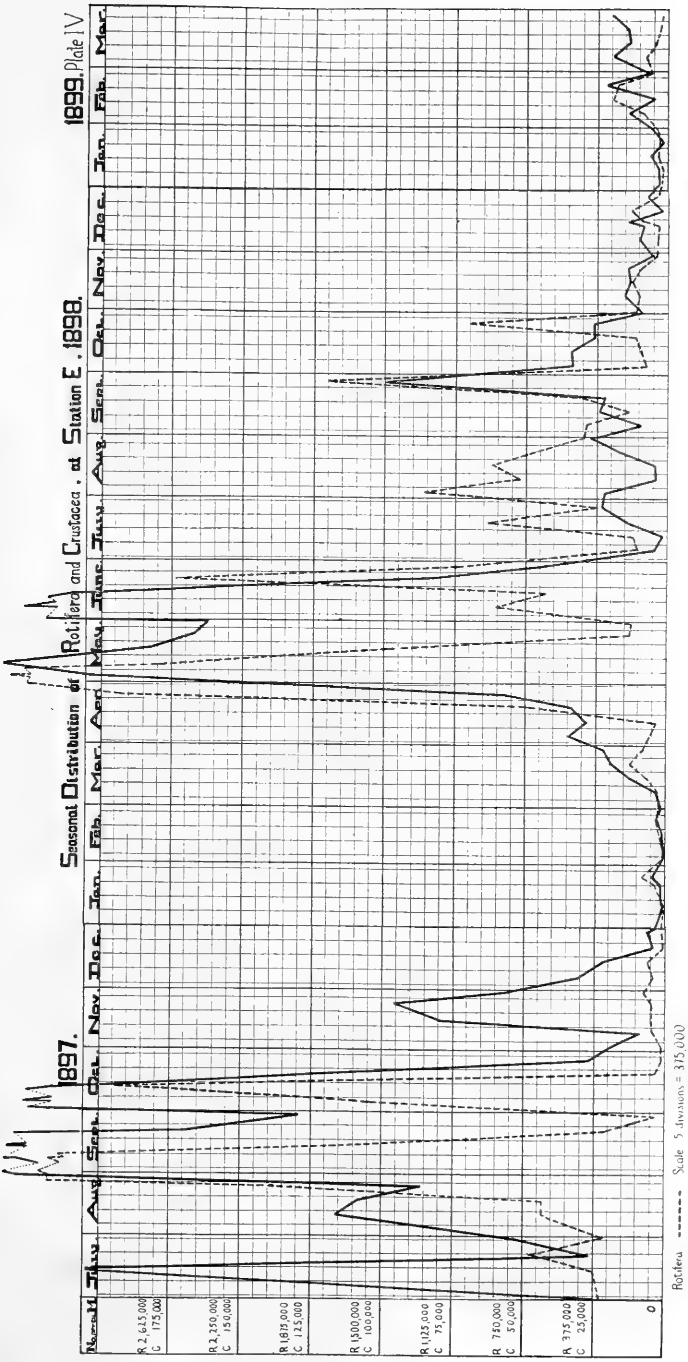
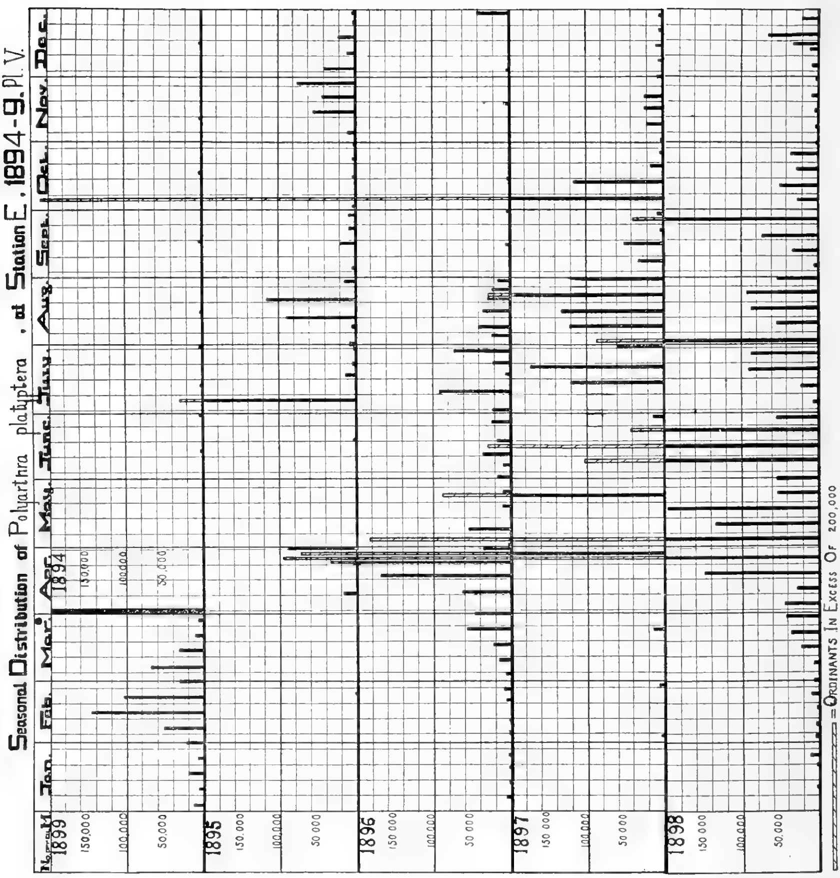


Plate III.
Seasonal Distribution of Rotifera and Crustacea, at Station E. 1895. 1896.
No. per M
July
Aug.
Sept.
Oct.
Nov.
Dec.
Jan.
Feb.
Mar.
Apr.
May.
June.
July.
Aug.
Sept.
Oct.
R 2,625,000 C 175,000
R 2,250,000 C 150,000
R 1,875,000 C 125,000
R 1,500,000 C 100,000
R 1,125,000 C 75,000
R 750,000 C 50,000
R 375,000 C 25,000
0
Rotifera ---- Scale 5 divisions = 375,000.
Crustacea —— " " " = 25,000.


Seasonal Distribution of Rotifera and Crustacea, at Station E. 1898.
1899. Plate IV
1897.
1898.
1899.
July. Aug. Sept. Oct. Nov. Dec. Jan. Feb. Mar. Apr. May. June. July. Aug. Sept. Oct. Nov. Dec. Jan. Feb. Mar.
R 2,625,000 C 175,000
R 2,250,000 C 150,000
R 1,875,000 C 125,000
R 1,500,000 C 100,000
R 1,125,000 C 75,000
R 750,000 C 50,000
R 375,000 C 25,000
0
Rotifera ------ Scale 5 divisions = 375,000
Crustacea —— " " " = 25,000


Seasonal Distribution of Polyarthra platyptera . at Station E, 1894-9. Pl. V.
Month
Jan. Feb. Mar. Apr. May. June. July. Aug. Sept. Oct. Nov. Dec.
1899 150,000 100,000 50,000
1894 150,000 100,000 50,000
1895 150,000 100,000 50,000
1896 150,000 100,000 50,000
1897 150,000 100,000 50,000
1898 150,000 100,000 50,000
= Ordinants In Excess Of 200,000

## ERRATA AND ADDENDA.

Page 58, line 7, for *ovalis* read *ovata.*

Page 85, line 8, for *longicaudus* read *longicauda*, and just above *Phacus pleuronectes* read the following paragraph:—

*Phacus longicauda* var. *torta*, n. var.—This variety, for which I propose the name *torta* because of the twisted body, is figured by Stein ('78, Taf. 20, Fig. 3). It occurred sparingly in midsummer from July to September, rarely in October, in 1896 and 1897.

Page 91, line 18, after *T. caudata* Ehrb. read *T. lagenella* Stein.

Pages 153, line 3 from bottom, 168, line 16, and 178, line 14, for *'98* read *'98a.*

Pages 156, line 11, 159, line 16, and 161, line 5 from bottom, for *'93* read *'98a.*

# BULLETIN

OF THE

# ILLINOIS STATE LABORATORY

OF

# NATURAL HISTORY

URBANA, ILLINOIS, U. S. A.

VOL. VIII. AUGUST, 1908 ARTICLE II.


## NEW GENERA AND SPECIES OF ILLINOIS THYSANOPTERA


BY

J. DOUGLAS HOOD

ARTICLE II.—*New Genera and Species of Illinois Thysanoptera.* BY J. DOUGLAS HOOD.

In the present paper, descriptions are given of five new genera and fifteen new species of Illinois Thysanoptera. For much of the material upon which these descriptions are based, I am indebted to several of my friends and associates, among whom may be mentioned Charles A. Hart, Robert D. and Hugh Glasgow, John J. Davis, Lindley M. Smith, Henry E. Ewing, James Zetek, Frank C. Gates, and George H. Coons.

In the measurements, non-chitinous portions have been excluded. For example, the length of the prothorax is taken to be its length along the median dorsal line, exclusive of the membrane connecting it with the head.

Type specimens are in the writer's collection, and in the collection of the Illinois State Laboratory of Natural History.

## SUBORDER **TEREBRANTIA** HALIDAY

### FAMILY THRIPIDÆ Uzel.

### HETEROTHRIPS gen. nov. (Fig. 1.)

(*ἕτερος*, other than usual; *θριψ*, thrips.)

Head wider than long. Ocelli present. Antennæ clearly nine-segmented; segments 3 and 4 conical, large, their combined lengths about equal to that of segments 5–9, each with an apical band enclosing small circular sensoria (?), disposed in two nearly regular transverse rows; segments 5–9 much narrower than 3 and 4, successively diminishing in diameter; segments 5–8 provided each with either one or two slender sense cones. Maxillary palpi three-segmented. Prothorax twice as long as head, sides decidedly arcuate; not armed with long spines. Second fore tarsal segment armed with a claw-like appendage. Fore wings long, narrow, pointed, with two longitudinal veins, separate for their entire length, and set with from 20 to 24 stout spines; costa similarly armed with stout spines which

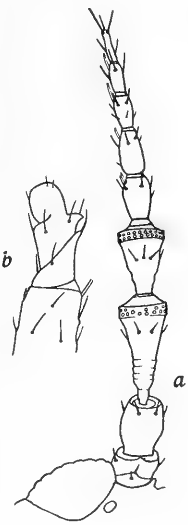



FIG. 1
*Heterothrips arisæmæ*, female. *a*, left antenna, dorsal view; *b*, right fore tarsus, outer side. (J. D. H., del.)

gradually increase in length toward apex of wing. Sides of abdomen reticulate, sparsely spinose; posterior margins of abdominal segments 2–8 prolonged into small equidistant flattened spines (excepting under the wings), which may be united at their bases into plates; tip of abdomen (in female) conical, tenth segment weakly chitinized in its apical median half; ovipositor well developed, curved downwards.

This genus, although seemingly a specialized one and suggesting *Sericothrips* Haliday, has retained certain primitive characters (the nine-segmented antennæ, the character of the sensoria, and the tarsal appendage) which indicate affinities with the Æolothripidæ. In view of the fact that in all the species of the order, a change in the number of antennal segments always consists in a reduction and never in an increase in the number of these segments, it might be assumed that the Thripidæ early divided into two branches, one of which, continuing more nearly along the original line, gave rise to the present genus, while the other produced the ordinary type of Thripidæ. *Heterothrips* is, indeed, so sharply separated from all other members of its family, that a new sub-family might easily be erected for it; but it seems best to defer this until the Thripidæ are better known.

### *Heterothrips arisæmæ* sp. nov. (Fig. 1.)

*Female.*—Length about 1.25 mm. Color nearly uniform dark blackish brown; tarsi, anterior tibiæ, and third antennal segment pale yellowish.

Head rather coarsely transversely striate, faintly but sharply constricted at posterior margin of eyes; frons acutely emarginate. Antennal segments 1 and 2 slightly lighter than body, shaded laterally with black, the former provided with a sub-transverse carina; segment 3 pale yellowish, with a narrow sub-basal white band, and apical third clouded with brown; segments 4–9 uniform light blackish brown, excepting the yellowish sub-apical band of sensoria on segment 4.

Prothorax about twice as long as head and two-thirds as long as wide; sides and angles rounded; surface sparsely spinose, and faintly reticulate. Pterothorax about 1.3 times as wide as prothorax, and about as long as wide; mesoscutum transversely striate, and with four pairs of short spines; metascutum concentrically striate. Wings just attaining tip of abdomen; basal third widened, the sub-basal width slightly more than twice the sub-apical, and contained in the total length about 7.6 times; color blackish brown, excepting a broad sub-basal white band. Legs reticulate; femora nearly concolorous with body, the anterior pair shading to yellow at apex; fore tibiæ yellow, shaded laterally with brown; middle and hind tibiæ blackish brown, extremities paler; all tarsi clear yellow.

Abdomen lanceolate, widest at segment 4; spines short, inconspicuous.

Measurements:—Total length 1.24 mm.; head, length .10 mm., width .18 mm.; prothorax, length .16 mm., width .24 mm.; pterothorax, width .32 mm.; abdomen, width .34 mm. Antennæ: 1, 28 μ; 2, 42 μ; 3, 84 μ; 4, 56 μ; 5, 34 μ; 6, 34 μ; 7, 25 μ; 8, 22 μ; 9, 25 μ; total, .37 mm.

*Male.*—Length .72–.80 mm.; prothorax, length .14 mm., width .22 mm.; mesothorax, width .22 mm.; abdomen, width .19 mm.

Brachypterous. Last ventral segment of abdomen with a broad, semicircular emargination, each side of which is an acute tooth.

Described from twelve females and two males, taken at Urbana, Illinois, in flowers of Jack-in-the-pulpit (*Arisæma triphyllum*), by Mr. Frank C. Gates.

### Genus SERICOTHRIPS Haliday, 1836.

#### *Sericothrips pulchellus* sp. nov.

*Female.*—Length about 1 mm. Color dark blackish brown to black, with bright red hypodermal pigmentation.

Similar to *S. variabilis* (Beach), differing from it as follows:

Head uniform gray-black. Antennal segments 1 and 2 dark blackish brown, the latter grayish yellow at middle; segments 3, 4, and 5 grayish yellow, 5 slightly clouded apically; segments 6–8 gray, the basal third of 6 grayish yellow.

Prothorax concolorous with head, with conspicuous black reticulation, and thickly dotted with black spots, the latter visible only under high power. Pterothorax nearly concolorous with prothorax, the red pigmentation usually quite conspicuous. Fore wings black, tipped with white, and with two broad white cross bands, one near base, other near apex. Femora nearly concolorous with body, pale basally; ground color of tibiæ pale yellow, the fore pair clouded basally and laterally with brown; middle and hind pairs pale at extreme base, beyond which they are concolorous with the femora to, or slightly beyond, middle; tarsi pale yellow.

Abdomen often pale at middle, and with segments 7–10 darker.

Measurements:—Total length 1.0 mm.; head, width .17 mm.; prothorax, length .14 mm., width .21 mm.; mesothorax, width .28 mm.; abdomen, width .31 mm. Antennæ: 1, 22 μ; 2, 39 μ; 3, 62 μ; 4, 59 μ; 5, 48 μ; 6, 53 μ; 7, 11 μ; 8, 14 μ; total, .31 mm.

*Male.*—Length about .7 mm. Coloration similar to that of female.

This species is very close to *S. variabilis* (Beach), but the coloration is distinctive. In living specimens, examined under a hand lens, the head and prothorax are velvety-black and without luster, due no doubt to the microscopic reticulation.

At Muncie, Illinois (the only locality from which I have seen specimens) this species was very abundant upon the hop tree (*Ptelea trifoliata*). As many as fifty individuals were frequently observed on the under surface of a single leaf, where their peculiar coloration rendered them very conspicuous.

## Suborder **TUBULIFERA** Haliday.*

### Family PHLŒOTHRIPIDÆ Uzel.

### Genus Zygothrips Uzel, 1895.

### *Zygothrips longiceps* sp. nov. (Fig. 2).

*Female*.—Similar to *Z. minutus* Uzel, from which it differs as follows:

*a*. Length about 1.1 mm. head about 1.1 times as long as wide, half as long as antennæ, and about 1.4 times as long as tube. Anterior marginal spines on prothorax large, subequal in length to the others. Posterior margins of abdominal segments 3–7 provided each with two pairs of straight spines, the inner pair short. Tarsi light yellow, tibiæ yellowish, the first and third pairs clouded at base, and the second pair at middle, with brown or black
*Z. minutus* Uzel.

*aa*. Length about 1.47 mm. Head about 1.4 times as long as wide, three-fifths as long as antennæ, and almost twice as long as tube. Anterior marginal spines on prothorax wanting. Posterior margins of abdominal segments 3–6 provided each with two pairs of long spines, the inner pair sigmoid. Tibiæ and tarsi uniform bright yellow
*Z. longiceps* sp. nov.

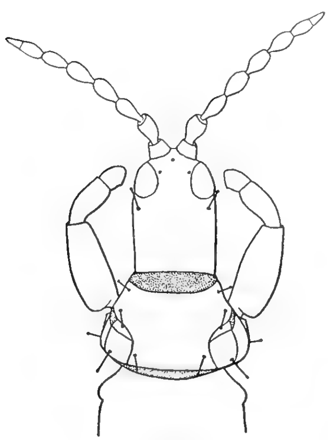


Fig. 2
*Zygothrips longiceps*, female, head and prothorax. (J. D. H., del.)

The measurements of the female of this species are as follows: Total length 1.47 mm.; head, length .192 mm., width .134 mm.; prothorax, length .123 mm., width (including coxæ) .232 mm.; pterothorax, width .234 mm.; abdomen, width .272 mm.; tube, length .102

*The division of the Tubulifera into the two families *Phlœothripidæ* and *Idolothripidæ*, proposed by R. S. Bagnall (Ann. and Mag. of Nat. Hist., Eighth Series, Vol. I., No. 4, p. 356; Apr., 1908), seems to be an unnatural one, apparently separating from each other species which are more closely related than the extremes of the respective families into which they fall.

mm., width at base .057 mm., at apex .032 mm. Antennæ: 1, 24 μ; 2, 44 μ; 3, 44 μ; 4, 46 μ; 5, 45 μ; 6, 41 μ; 7, 38 μ; 8, 24 μ; total, .30 mm.

Described from a single brachypterous female taken by the writer in a gall on *Solidago*, at Carbondale, Illinois, June 20, 1907.

## LISSOTHRIPS gen. nov.

(*λισσός*, smooth; *θρίψ*, thrips.)

Head slightly wider than long, sub-globose, narrowed posteriorly; eyes directed forwards; cheeks full, sparsely spinose. Antennæ about twice as long as head, eight-segmented; segments 1 and 2 broadest; 3 very small, shorter and narrower than any of the following segments, excepting the distal one; 7 longest. Mouth cone broad, pointed, surpassing base of prosternum. Prothorax shorter than head, with five pairs of very long bristles. Fore tarsi unarmed.

This genus is closely related to *Cephalothrips* Uzel, but the longer, pointed mouth cone and the structure of the antennæ are sufficiently distinctive to warrant the erection of a new genus.

### *Lissothrips muscorum* sp. nov.

*Female.*—Length about 1.17 mm. Color blackish brown to black, legs and antennal segments 1 and 2 paler.

Eyes moderate in size, coarsely faceted, situated on anterior surface of head. Ocelli lacking. Postocular spines long, blunt, expanded distally.

Prothorax three-fourths as long as head; spines slightly expanded at tips; mid-lateral spines and the pair at the posterior angles almost as long as prothorax. Pterothorax about as long as, and slightly narrower than prothorax; mesonotum with one long spine at each posterior angle.

Abdomen one and one-third times as wide as prothorax; posterior borders of abdominal segments 2–9 each with two pairs of very long, subequal, pointed bristles, some twice the length of the abdominal segments.

Measurements:—Total length about 1.17 mm.; head, length .16 mm., width .17 mm.; prothorax, length .12 mm., width (including coxæ) .28 mm.; pterothorax, width .26 mm.; abdomen, width .36 mm.; tube, length .12 mm., width at base .070 mm., at apex .034 mm. Antennæ: 1, 25 μ; 2, 43 μ; 3, 32 μ; 4, 42 μ; 5, 42 μ; 6, 46 μ; 7, 48 μ; 8, 36 μ; total, .31 mm.

Described from several apterous females, from Arcola, Dubois, Mahomet, Marion, Muncie, Pulaski, and Urbana, Illinois, taken in moss.

## Genus Trichothrips Uzel, 1895.

### *Trichothrips americanus* sp. nov. (Fig. 3).

*Female.*—Forma brachyptera.—Length about 1.7 mm. General color clear brownish yellow with more or less dark hypodermal pigmentation; prothorax and basal abdominal segments slightly darkened with brownish black; tube tipped with gray.

Head slightly longer than wide; vertex elevated, rugose, sloping abruptly to bases of antennæ; cheeks rounded, faintly reticulate, sparsely spinose; postocular bristles slender, pointed. Eyes reduced. Ocelli wanting. Antennæ slightly more than twice as long as head; segments 1 and 2 concolorous with body, shaded laterally with black; 3–8 uniform dark blackish brown, excepting extreme base of 3, which is yellow; 3 subconical; 4–7 oblong, pedicellate, subequal in length, but becoming gradually narrower; 8 lanceolate, pedicellate; segments 3 and 4 each with two outer sense cones and one inner one; 5 and 6 each with one sense cone on either side of apex, the outer one on segment 6 very small. Mouth cone just attaining base of prosternum; labium broadly rounded; labrum pointed, surpassing labium by the length of the maxillary palpus.

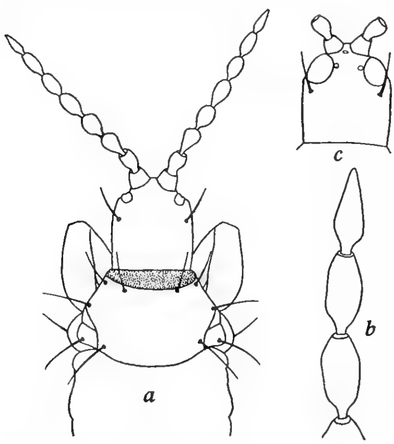



Fig. 3

*Trichothrips americanus*, female. *a*, head and prothorax, brachypterous form; *b*, tip of right antenna, dorsal view, brachypterous form; *c*, head, macropterous form. (J. D. H. et J. Z., del.)

Prothorax slightly shorter than head, and (including coxæ) about twice as wide as long; all spines present, long, pointed. Pterothorax about as long as, and usually somewhat narrower than, prothorax. Wings short, attaining base of abdomen. Legs about concolorous with body, all femora shaded laterally with brown or black; tarsal cups black; fore tarsi armed with a small, acute tooth.

Abdomen large, heavy, about one and one-third times as wide as prothorax. Tube slightly shorter than head, twice as wide at base as at apex.

Measurements:—Total length 1.68 mm.; head, length .21 mm., width .19 mm.; prothorax, length .18 mm., width (including coxæ) .38 mm.; pterothorax, width .36 mm.; abdomen, width .50 mm.; tube, length .18 mm., width at base .098 mm., at apex .045 mm. Antennæ: 1, 36 $\mu$; 2, 56 $\mu$; 3, 62 $\mu$; 4, 59 $\mu$; 5, 62 $\mu$; 6, 59 $\mu$; 7, 57 $\mu$; 8, 57 $\mu$; total, .45 mm.

Forma macroptera.—Similar to *forma brachyptera* in size; general color darker, the entire body shaded with grayish brown.

Head broadly rounded in front. Ocelli present. Eyes large, finely faceted. Pterothorax wider than prothorax. Wings large, reaching base of tube; color light gray-brown, spotted with darker.

*Male* (Forma brachyptera).--Similar to female, but smaller (length about 1.4 mm.). Prothorax about as long as head. Fore tarsi armed with a slightly larger tooth. Abdomen slender, tapering more gradually to apex.

Described from several specimens from Carbondale, Homer, and Urbana, Illinois, taken under bark on rotten stumps.

## *Trichothrips angusticeps* sp. nov. (Fig. 4).

*Female.*—Length about 1.4 mm. General color brownish yellow with considerable maroon-colored hypodermal pigmentation; head, prothorax, sides of abdomen, and tip of tube slightly darkened with brownish black.

Similar to *T. americanus* sp. nov., differing from it as follows:

Head fully 1.4 times as long as wide; cheeks parallel; postocular bristles knobbed. Antennæ 1.7 times as long as head, nearly concolorous with darker parts of body, excepting segments 1 and 2, and basal half of 3, which are paler. Mouth cone considerably surpassing base of prosternum; labrum surpassing labium by twice the length of the maxillary palpus.

Prothorax about .7 as long as head; all spines present, long, knobbed. Legs yellow, all femora shaded slightly with brownish.

Abdomen rather slender; tube .6 as long as head.

Measurements:—Total length 1.44 mm.; head, length .22 mm., width .16 mm.; prothorax, length .16 mm., width (including coxæ) .34 mm.; pterothorax, width .30 mm.; abdomen, width .42 mm.; tube, length .14 mm., width at base .081 mm., at apex .038 mm. Antennæ: 1, 31 $\mu$; 2, 49 $\mu$; 3, 53 $\mu$; 4, 50 $\mu$; 5, 53 $\mu$; 6, 50 $\mu$; 7, 48 $\mu$; 8, 50 $\mu$; total, .38 mm.

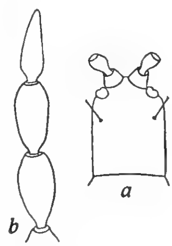



FIG. 4
*Trichothrips angusticeps*, female, brachypterous form. *a*, head; *b*, tip of right antenna, dorsal view. (J. D. H., del.)

*Male.*—Similar to female, but smaller (length about 1.25 mm.). Prothorax five-sevenths as long as head.

Described from eight brachypterous specimens, one of which is a male, taken under bark on rotten stumps, at St. Joseph and Urbana, Illinois, by Mr. C. A. Hart and the writer.

## *Trichothrips longitubus* sp. nov.

*Female.*—Length about 1.8 mm. General color dark blackish brown to black, pterothorax and basal abdominal segments usually paler; tibiæ, tarsi, and intermediate antennal segments bright lemon-yellow, the tibiæ clouded basally.

Head about as wide as long; cheeks slightly converging posteriorly; vertex elevated, slightly produced, and bearing the anterior ocellus at its extremity; lateral and dorsal surfaces noticeably transversely striate, sparsely and briefly spinose; postocular bristles blunt, almost half as long as head. Eyes slightly more than one-fourth as long as head, finely faceted. Ocelli anterior; anterior ocellus overhanging. Antennæ slightly less than twice as long as head; segments 1 and 2 nearly concolorous with body, 2 brownish yellow apically; 3–6 uniform bright lemon-yellow; 7 blackish yellow at base, shading to blackish brown at apex; 8 blackish brown; sense cones long, slender; segment 3 with one on outer apical surface; 4–6 each with one on either side of apex, and a small rudimentary one on dorsum. Mouth cone nearly reaching base of prosternum.

Prothorax two-thirds as long as head, and (including coxæ) about two and one-half times as wide as long; all spines present, blunt, excepting the pair at the posterior angles, which are pointed, and longer than the prothorax. Pterothorax broader than long, slightly wider than prothorax; sides arcuate, slightly converging posteriorly. Wings reaching base of tube; fore wings clouded at base, not narrowed at middle, and with the apical fringe on posterior margin double for about eight hairs. Legs slender; femora nearly concolorous with body, the middle and hind pairs paler basally; tibiæ lemon-yellow, clouded basally; tarsi lemon-yellow, unarmed.

Abdomen large, heavy; bristles long. Tube fully as long as head, tapering evenly from base to apex.

Measurements:—Length 1.84 mm.; head, length .25 mm., width .24 mm.; prothorax, length .16 mm., width (including coxæ) .40 mm.; pterothorax, width .44 mm.; abdomen, width .46 mm.; tube, length .26 mm., width at base .105 mm., at apex .050 mm. Antennæ: 1, 30 $\mu$; 2, 57 $\mu$; 3, 73 $\mu$; 4, 68 $\mu$; 5, 68 $\mu$; 6, 65 $\mu$; 7, 68 $\mu$; 8, 46 $\mu$; total, .48 mm.

*Male.*—Similar to female. Prothorax and fore femora not enlarged; fore tarsi unarmed.

Described from ten macropterous specimens (nine females and one male) taken in sweepings at Carbondale, Illinois, by Mr. C. A. Hart.

This species is easily distinguished from all other members of its genus by the peculiar antennal coloration and the long tube.

## *Trichothrips buffæ* sp. nov. (Fig. 5).

*Female*.—Length about 1.9 mm. General color black; antennal segments 1–3, tarsi, and articulations of legs, usually yellowish brown.

Head nearly as wide as long, broadly rounded in front; cheeks slightly converging posteriorly; lateral and dorsal surfaces noticeably transversely striate, sparsely, briefly, and scarcely visibly spinose; postocular bristles blunt, slightly longer than eyes. Eyes almost one-third as long as head. Ocelli anterior; anterior ocellus scarcely overhanging. Antennæ slightly more than twice as long as head, faintly reticulate; segments 4–8 concolorous with body; 1 and 3 usually slightly paler, darkened laterally, the latter pale yellow at extreme base; 2 brownish yellow, darkened laterally and basally; sense cones long, slender; segment 3 with one on outer apical surface; 4–6 each with one on either side of apex and 5 and 6 each with a rudimentary additional one on dorsum; 7 with a long, sub-apical one on dorsum. Mouth cone long, attaining base of prosternum.

Prothorax about as long as head, and (including coxæ) slightly more than twice as wide as long; all spines present, blunt, the pair at the posterior angles longest. Pterothorax rectangular, slightly wider than prothorax, and about one and one-third times as wide as long. Wings short, attaining base of abdomen. Fore femora not enlarged; fore tarsi unarmed.

Abdomen large, heavy, 1.3 times as wide as prothorax, narrowing roundly from segment 6 to base of tube. Tube slightly shorter than head, tapering evenly from base to apex.

Measurements:—Total length 1.87 mm.; head, length .21 mm., width .20 mm.; prothorax, length .19 mm., width (including coxæ) .42 mm.; pterothorax, width .43 mm.; abdomen, width .54 mm.; tube, length .20 mm., width at base .094 mm., at apex .042 mm. Antennæ: 1, 30 μ; 2, 56 μ; 3, 64 μ; 4, 63 μ; 5, 62 μ; 6, 63 μ; 7, 62 μ; 8, 42 μ; total, .44 mm.

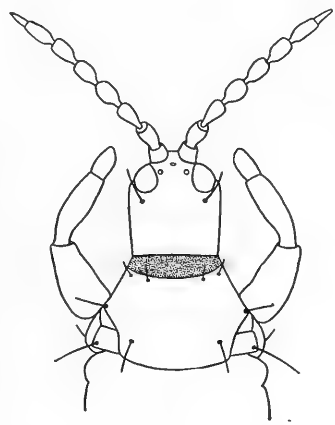


FIG. 5
*Trichothrips buffæ*, female, head and prothorax. (J. D. H., del.)

*Male*.—Similar to female, but smaller (length 1.5 mm.). Prothorax and fore femora not enlarged; fore tarsi unarmed.

Described from several brachypterous specimens of both sexes taken under bark on soft maple trees at Decatur, Homer, and Urbana, Illinois.

I name this species for Dr. Pietro Buffa, of the Royal University of Pisa, Italy.

## Plectrothrips, gen. nov.

(πλῆκτρον, spur; θρίψ, thrips.)

Head slightly longer than wide; cheeks full, without spine-bearing warts; vertex elevated, transverse. Eyes moderately large. Ocelli present, anterior. Antennæ inserted beneath vertex, twice as long as head, eight-segmented; segments 3–6 provided each with two or three short, stout, roughened sense cones; segment 8 noticeably longer than segment 7, very slender, compressed, provided with a single terminal bristle. Mouth cone very small, only about one-fourth as long as prothorax, slightly wider than long, broadly rounded at apex; labrum blunt. Prothorax large, heavy, one and one-third times as long as head, with a prominent median groove; notum not attaining lateral margins; all spines wanting; excepting the pair at the posterior angles. Pterothorax large, lateral outline convex. Legs short, stout; fore tibiæ with a stout, obtuse tooth on inner margin of apex; middle and hind tibiæ with respectively one and two long, very stout, tibial spurs on inner lower margin of apex; anterior femora very large; fore tarsi with a very large, slightly curved, acute tooth. Wings present, not narrowed at middle. Male without scale at base of tube.

This genus resembles *Trichothrips* Uzel in general structure, and should probably follow it in a linear arrangement of the genera.

### *Plectrothrips antennatus* sp. nov.

*Female.*—Length about 1.8 mm. General color blackish brown, fading to brownish yellow on abdomen; tube bright brownish orange.

Head six-sevenths as wide as long, truncate in front, widest behind eyes, and narrowed posteriorly; lateral and dorsal surfaces very faintly reticulate, sparsely spinose; postocular bristles slender, pointed, their bases situated near the lateral margins of head, and equidistant from posterior margins of eyes and anterior border of prothorax. Eyes finely faceted, moderately large. Ocelli placed well forward; anterior ocellus slightly overhanging; posterior ocelli opposite anterior third of eyes and contiguous to them. Antennæ eight-segmented; segments 2–8 subequal in length; 8 compressed, fusiform-pedicellate as seen from above, and with a single terminal bristle; 3, 5, and 6 provided each with two short, very stout, roughened sense cones, one on each side of apex; 4 with an additional similar cone on the outer apical surface; circular sense-area on segment 2 situated nearer base than usual; antennæ concolorous with body, excepting segment 3, which is orange at base.

Prothorax large, one and one-third times as long as head, and (including coxæ) two-thirds as long as wide; all the usual spines lacking, save a single long pointed one at each posterior angle. Pterothorax slightly broader than long, and a little wider than prothorax; sides rather prominently arcuate. Wings reaching about to base of tube, veinless; fore wings with an apical double fringe of eight hairs, and with the basal scale black. Femora concolorous with head and thorax; tibiæ and tarsi yellowish brown.

Abdomen large; sides sub-parallel as far as segment 6, thence curving roundly to base of tube. Tube about three-fifths as long as head, abruptly narrowed at apex, and slightly narrowed at middle.

Measurements:—Total length 1.8 mm. (1.71–1.89 mm.); head, length .32 mm., width .19 mm.; prothorax, length .27 mm., width (including coxæ) .40 mm.; pterothorax, width .41 mm.; abdomen, width .45 mm.; tube, length .13 mm., width at base .082 mm., at apex .041 mm. Antennæ: 1, 41 $\mu$; 2, 52 $\mu$; 3, 57 $\mu$; 4, 55 $\mu$; 5, 54 $\mu$; 6, 54 $\mu$; 7, 49 $\mu$; 8, 54 $\mu$; total, .42 mm.

*Male.*—Slightly smaller than female (total length about 1.4 mm.). Abdomen more slender, tapering more gradually toward apex.

Described from two females and five males, taken by the writer in June on a window of a wood-shed, Urbana, Illinois.

This species could not possibly be confused with any other described one, distinguished as it is by characters of generic significance.

NEOTHRIPS gen. nov. (Fig. 6).

(*νέος*, new; *θριψ*, thrips.)

Head almost one and one-half times as long as wide; cheeks parallel, sparsely spinose; vertex elevated, narrowed anteriorly, not overhanging. Antennæ stout, eight-segmented, about one and three-fourths times as long as head, inserted beneath vertex; segments 7 and 8 distinct, but united into a heavy, compact club, and with a straight, comb-like, ventral row of either nine or ten bristles; segments 2 and 7 slightly longer than the intermediate ones, which are almost exactly equal in length. Mouth cone long, slender, acute, surpassing base of prosternum; labrum pointed. Prothorax large, trapezoidal, armed with five pairs of bristles. Legs short, stout; fore tarsi armed with an acute tooth which in the male is larger and slightly curved. Male without scale at base of tube.

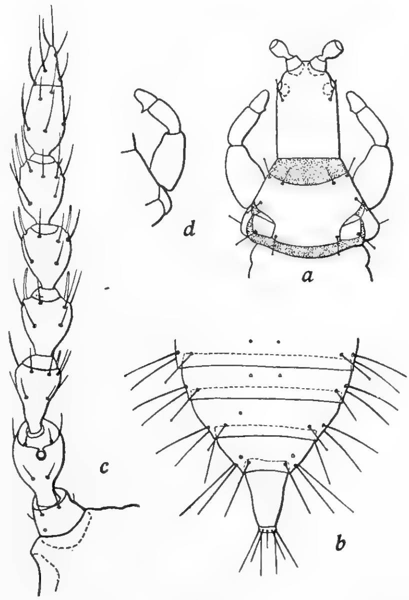



FIG. 6
*Neothrips corticis.* *a*, head and prothorax, female; *b*, tip of abdomen, female; *c*, right antenna, dorsal view, female; *d*, right fore leg, male. (J. D. H., del.)

This genus is perhaps more closely related to *Allothrips* gen. nov. than to any other, standing between it and *Plectrothrips* gen. nov.

## *Neothrips corticis* sp. nov. (Fig. 6).

*Female.*—Length about 1.34 mm. Color nearly uniform light yellowish brown, with considerable irregular reddish brown hypodermal pigmentation; tube bright orange-brown, darker at middle.

Eyes very small, consisting of a few large, lateral facets; ocelli wanting. Antennæ nearly concolorous with body, segments 1 and 2 often slightly darkened laterally; sense-cones long, slender, segments 3 and 6 each with one and segments 4 and 5 each with two; three bristles on ventral surface of segment 7.

Pterothorax about as wide as prothorax, its dorsum two-thirds as long as wide. Wings rudimentary. Tarsi and apices of tibiæ yellow; femora and basal three-fourths of tibiæ nearly concolorous with body, lighter along inner surface.

Abdomen large, heavy, about one and one-half times as wide as prothorax; sides sub-parallel as far as segment 6, and then converging abruptly to base of tube. Tube .7 as long as head, and about 1.4 times as long as its basal width; abruptly narrowed at apex and slightly narrowed at middle, where it is more heavily chitinized.

Measurements:—Total length about 1.34 mm.; head, length .20 mm., width .14 mm.; prothorax, length (excluding non-chitinous portions) .15 mm., width (including coxæ) .29 mm.; pterothorax, width .28 mm.; abdomen, width .42 mm.; tube, length .14 mm., width at base, .095 mm., at apex, .036 mm. Antennæ: 1, 31 $\mu$; 2, 54 $\mu$; 3, 46 $\mu$; 4. 44 $\mu$; 5, 44 $\mu$; 6, 45 $\mu$; 7, 50 $\mu$; 8, 29 $\mu$; total, .34 mm.

*Male.*—Slightly smaller than female (length about 1.2 mm.). Four bristles on ventral surface of segment 7. Abdomen more slender (about one and one-fifth times as wide as prothorax), tapering evenly from segment 7 to base of tube.

Described from several specimens of both sexes taken under bark at Urbana and Hillery, Illinois, in winter.

## Allothrips gen. nov. (Fig. 7).

(ἄλλος, of another kind; θρίψ, thrips.)

Head large, about as wide as long; cheeks full, sparsely spinose· vertex elevated between eyes, and sloping abruptly to insertion of antennæ. Antennæ stout, seven-segmented, less than 1.6 times as long as head, inserted beneath vertex; segments 3–6 subequal in length, very slightly longer than wide; 2 and 7 longer, the latter with a slightly arcuate row of four bristles on its ventral surface.

Mouth cone large, broadly rounded, reaching base of prosternum; labrum blunt. Prothorax short, about two-thirds as long as head, and armed with six pairs of knobbed bristles. Legs short, stout; fore tarsi unarmed.

This genus is the only one of its family (excepting *Kladothrips* Froggatt) which has seven-segmented antennæ. The reduction in the number of antennal segments is a result of the union of the two apical ones, and the whole antenna is an exaggeration of the type indicated by *Neothrips* gen. nov., in which a separating suture is still distinctly visible.

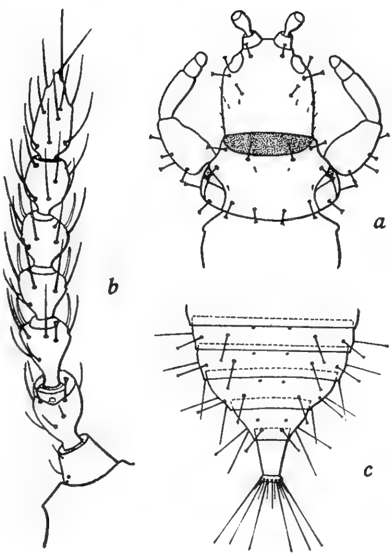



FIG. 7
*Allothrips megacephalus*, female, apterous form. *a*, head and prothorax; *b*, right antenna, dorsal view; *c*, tip of abdomen. (J. D. H., del.)

*Allothrips megacephalus* sp. nov. (Fig. 7).

*Female*.—Length about 1.3 mm. Color dark blackish brown, with maroon-colored hypodermal pigmentation; tarsi, tube, and antennal segments 1 and 2 slightly lighter. Abdomen broad, about one and one-half times as wide as prothorax.

Forma aptera.—Eyes very small, consisting of a few large lateral facets. Ocelli lacking. Pterothorax about as long as prothorax; mesonotum transverse, sub-rectangular, with six equidistant knobbed bristles along its posterior border, and with an additional similar pair near the posterior angles.

Measurements:—Total length 1.31 mm.; head, length .21 mm., width .20 mm.; prothorax, length .14 mm., width (including coxæ) .30 mm.; pterothorax, width .30 mm.; abdomen, width .45 mm; tube, length .12 mm., width at base .082 mm., at apex .044 mm. Antennæ: 1, 38 $\mu$; 2, 57 $\mu$; 3, 51 $\mu$; 4, 41 $\mu$; 5, 44 $\mu$; 6, 44 $\mu$; 7, 67 $\mu$; total, .34 mm.

Forma brachyptera.—Eyes moderately large, coarsely faceted. Ocelli present; a pair of long knobbed bristles behind the posterior ones. Pterothorax about twice as long as prothorax; mesonotum sub-pentagonal, with two pairs of knobbed bristles along its posterior border. Wings attaining base of abdomen.

Described from several females, one of them brachypterous, taken under bark on various trees at Urbana and Springfield, Illinois, in winter.

## Genus ACANTHOTHRIPS Uzel, 1895.

This genus is represented in Illinois by two species, which may readily be distinguished from each other and from their previously described congeners by means of the following key.

I. Inner-surface of fore femora with a single sub-apical tooth.

*a.* Cheeks with prominent spine-bearing warts. No latero-dorsal white stripe.

*b.* Wings of both pairs with a very prominent blackish longitudinal vein reaching nearly to tip
*A. magnafemoralis* Hinds.*

*bb.* Wings without conspicuous longitudinal vein
*A. doaneii* Moulton, *A. nodicornis* (Reuter).

*aa.* Cheeks without spine-bearing warts. A latero-dorsal white stripe . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . *A. albivittatus* sp. nov.

II. Inner surface of fore femora with a "long, sharp, and slightly curved" tooth near base. . . . . . . . . . . . . . . . . . . . . . . . . . . *A. sanguineus* Bagnall.

### *Acanthothrips albivittatus* sp. nov.

*Female.*—Length about 2.1 mm. Dorsal surface roughened with numerous microscopic tubercles; ventral surface smooth. General color (reflected light) dull mahogany brown, with a narrow latero-dorsal white stripe which originates at the posterior margin of the eye and terminates in a small spot at base of segment 8 of abdomen; on the head the stripe is slightly narrower than the basal antennal segment; on the prothorax it broadens posteriorly and includes an irregular reddish spot; at the anterior mesothoracic margin it is broken up into two subequal triangular areas, from which it continues as a much narrower line to the base of the abdomen; it is lacking on the first abdominal segment, and extends uninterruptedly from the second to the eighth. General color (transmitted light) yellowish brown, with maroon-colored hypodermal pigmentation; legs blackish brown, non-pigmented, shaded laterally with black; tarsi and inner surface of fore tibiæ paler; antennæ uniform black.

Head 1.4 times as long as wide; cheeks converging abruptly to eyes and to base of head; dorsal and lateral surfaces faintly reticulate, scarcely visibly spinose and not roughened by spine-bearing tubercles; postocular bristles long, pointed†. Eyes large, contained in length of head two and two-thirds times, and wider than the interval between them. Ocelli sub-approximate, opposite center of eyes. Antennæ about one and one-fourth times as long as head; segments 3–6 urn-shaped; 7 and 8 closely united, the latter conical; sense cones long, slender; segments 3, 5, and 6 each with one on either side of apex; 4 with an additional

*I have specimens of this species taken at Muncie and Urbana, Illinois.

†These bristles are wanting in *A. magnafemoralis* Hinds.

outer one; 7 with a sub-apical dorsal one. Mouth cone pointed, attaining base of prosternum.

Prothorax two-thirds as long as head, and (including coxæ) slightly less than twice as wide as long; all usual spines present, blunt. Pterothorax scarcely wider than prothorax; sides sub-parallel, slightly concave. Wings long, without prominent longitudinal vein. Fore femora five-eighths as wide as length of prothorax, and with a sub-apical acute tooth; fore tarsi armed with a stout tooth.

Abdomen about as wide as prothorax. Tube about .7 as long as head; bristles at tip shorter than head.

Measurements:—Total length 2.1 mm.; head, length .36 mm., width .25 mm.; prothorax, length .24 mm., width (including coxæ) .46 mm.; pterothorax, width .46 mm.; abdomen, width .47 mm.; tube, length .25 mm., width at base .092 mm., at apex .059 mm. Antennæ: 1, 45 $\mu$; 2, 70 $\mu$; 3, 118 $\mu$; 4, 112 $\mu$; 5, 100 $\mu$; 6, 73 $\mu$; 7, 67 $\mu$; 8, 38 $\mu$; total, .62 mm.

Described from one female taken on the trunk of a Carolina poplar at Bloomington, Illinois, July 10, by Hugh Glasgow.

## Genus Liothrips Uzel, 1895.

### *Liothrips* (?) *ocellatus* sp. nov.

*Female.*—Length about 2.2 mm. General color black, excepting tarsi and articulations of legs, which are slightly paler, and antennal segments 3–5, which are at least partly yellow.

Head 1.15 times as long as wide, widest just behind eyes, narrowing evenly to base, where it is .84 of the postocular width; vertex elevated between eyes, slightly overreaching insertion of antennæ, and bearing the anterior ocellus at its extremity; lateral and dorsal surfaces transversely striate, sparsely, briefly, and scarcely visibly spinose; postocular bristles blunt, three-fifths as long as eyes. Eyes large, one-third as long as head. Ocelli anterior; posterior ocelli opposite anterior third of eyes: anterior ocellus overhanging. Antennæ eight-segmented, twice as long as head; segments 1 and 2 concolorous with body, excepting apex of 2, which is paler apically; 3 uniform bright lemon-yellow; 4 yellow, dusky at base and apex; 5 blackish brown, its second and third fifths brownish yellow; segments 6–8 concolorous with body.*

Prothorax two-thirds as long as head, and (including coxæ) 2.4 times as wide as long; all spines present, moderately long, blunt, the two pairs near the posterior angles longest. Pterothorax slightly wider than prothorax, about as long as broad, slightly narrower posteriorly; sides convex, gently arcuate. Wings present, reaching about to base of tube; fore wings brownish at base, not narrowed at middle, with three sub-

*I have not described the position of the sense-cones, as several of these are apparently lacking.

basal brownish spines on anterior margin, and with the apical fringe on the posterior margin double for fourteen hairs; posterior wings with a weak median vein reaching about to middle. Legs stout, not long; fore tarsi unarmed.

Abdomen large, slightly wider than pterothorax, tapering roundly from segment 6 to base of tube. Tube about .8 as long as head, tapering evenly from base to apex.

Measurements:—Total length 2.21 mm.; head, length .24 mm., width .21 mm.; prothorax, length .16 mm., width (including coxæ) .38 mm.; pterothorax, width .42 mm.; abdomen, width .46 mm.; tube length .20 mm., width at base .092 mm., at apex .042 mm. Antennæ 1, 36 μ; 2, 62 μ; 3, 81 μ; 4, 81 μ; 5, 73 μ; 6, 67 μ; 7, 62 μ; 8, 35 μ; total .50 mm.

Described from a single female taken at Hillery, Illinois, in moss, by C. A. Hart and James Zetek.

## Genus Cryptothrips Uzel, 1895.

### *Cryptothrips carbonarius* sp. nov. (Fig. 8).

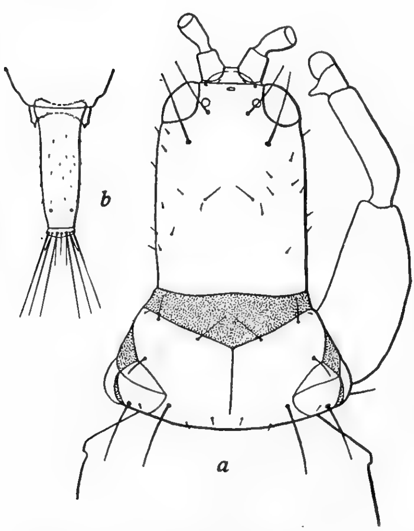



Fig. 8
*Cryptothrips carbonarius*, male. *a*, head and prothorax; *b*, tube. (J. D. H., del.)

*Male.*—Length about 2.22 mm. (abdominal segments somewhat telescoped). Color uniform coal-black, excepting tarsi and articulations of legs, which are dark blackish brown.

Head rectangular, about one and one-half times as long as wide, sides parallel; lateral and dorsal surfaces faintly reticulate, set with a number of short spines and a longer pair at middle of dorsum; vertex transverse; postocular spines long, slender, pointed; spines just behind ocelli about equal in length to the postocular. Eyes moderately large, not protruding, occupying the anterior angles of head. Ocelli moderately large, their diameter about three times that of facets of eyes; anterior ocellus not overhanging; posterior ocelli opposite centers of eyes and almost touching their inner margins. Antennæ eight-segmented, 1.4 times as long as head, uniform black in color; segments 3–6 sub-clavate; 7 fusiform, pedicellate; 8 fusiform. Mouth cone somewhat wider than long, apex broadly rounded; tip of labrum just attaining tip of labium.

Prothorax about three-fifths as long as width of head, and (including coxæ) about three times as wide as long; usual spines all present, the two pairs near the posterior angles much the longest; anterior marginals moderately long. Pterothorax about 1.4 times as wide as long, somewhat broader than prothorax; sides nearly straight, slightly converging posteriorly; anterior corners scarcely projecting beyond the general outline. Wings present.* Legs nearly concolorous with the body; anterior tarsi armed with a stout tooth. Abdomen moderately stout, about as broad as pterothorax, widest at about segment 3, from which it tapers evenly to segment 6, and then rather abruptly to base of tube. Tube four-sevenths as long as head, widest at base, constricted just before apex; intermediate portion parallel-sided, exactly three-fourths the diameter of base; surface not spinose.

Measurements:—Total length 2.22 mm.; head, length .46 mm., width .30 mm.; prothorax, length .17 mm., width (including coxæ) .49 mm.; pterothorax, width .52 mm.; abdomen, width .62 mm.; tube, length .27 mm., width at base .104 mm., at apex .054 mm. Antennæ: 1, 61 $\mu$; 2, 78 $\mu$; 3, 123 $\mu$; 4, 106 $\mu$; 5, 97 $\mu$; 6, 81 $\mu$; 7, 57 $\mu$; 8, 47 $\mu$; total .65 mm.

Described from a single macropterous male, taken at Pulaski, Ill., May 21, 1907, in sweepings from grass and weeds, by Mr. C. A. Hart.

## Genus Idolothrips Haliday, 1852.

### *Idolothrips flavipes* sp. nov. (Fig. 9).

*Female.*—Length about 3.1 mm. Color of body coal black; all tibiæ and tarsi, and at least the basal portion of antennal segments 3 to 6, bright yellow.

Head very slightly more than twice as long as wide, narrower just behind eyes and at base, widest across eyes; finely striated and set with several stout spines; vertex conical, produced, apex overhanging insertion of antennæ; anterior portion of head provided with a pair of prominent bristles in addition to the postocular, situated on either side of the prolonged vertex. Eyes large, finely faceted, prominent, bulging. Ocelli small, their diameter about equal to that of facets of eyes; anterior ocellus occupying extreme vertex; posterior ocelli slightly in front of centers of eyes, and slightly removed from their inner margins. Antennæ eight-segmented, slender, about 1.4 times as long as head; seg-

*The only specimen which I have of this species has been cleared in potassium hydroxide, and the wings, as a consequence, are unfit for study.

ments 3–5 clavate; 6–8 fusiform; segments 1, 2, 7, 8, apical half of 6, and apical fourth of 5, dark blackish brown; remainder of antenna lemon-yellow, excepting apex of 4, which is clouded with brown. Mouth cone about as long as its width at base, broadly rounded; tip of labrum just attaining tip of labium.

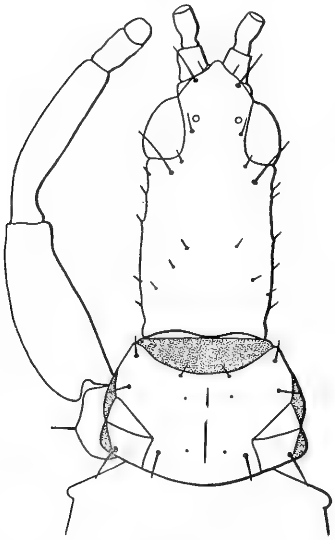


FIG. 9
*Idolothrips flavipes*, female, head and prothorax. (J. D. H., del.)

Prothorax almost as long as width of head, and (including coxæ) slightly more than twice as wide as long; surface finely reticulate; usual spines all present, the two pairs near the posterior angles somewhat longer than the others. Pterothorax sub-rectangular, about two-thirds as long aswide, and slightly broader than prothorax; anterior corners projecting slightly beyond the lateral margins. Wings represented by small pads, which are about equal in length to the head, and four times as long as broad. All tibiæ and tarsi bright yellow, the former often clouded with brown at base; remainder of legs concolorous with body· anterior tarsi unarmed.

Abdomen broad, about one and one half times as wide as pterothorax, widest at segment 4, from which it tapers evenly to tube, giving the abdomen a lanceolate form. Tube almost as long as head, tapering evenly to middle, and then some what more abruptly to apex; surface not spinose.

Measurements:—Total length 2.82–3 .34 mm.; head, length .53 mm., width .25 mm.; prothorax, length .21 mm., width (including coxæ) .46 mm.; pterothorax, width .48 mm.; abdomen, width .74 mm.; tube, length .47 mm., width at base .114 mm., at apex .052 mm. Antennæ: 1, 48 $\mu$; 2, 70 $\mu$; 3, 140 $\mu$; 4, 120 $\mu$; 5, 112 $\mu$; 6, 92 $\mu$; 7, 67 $\mu$; 8, 70 $\mu$; total, .72 mm.

*Male.*—Smaller than female (total length 2.58–2.97 mm.). Anterior femora no stouter than in female; fore tibiæ provided with a stout tooth. Abdomen slender, tapering evenly from almost the very base.

Described from several males and females, all from Illinois, as follows: Dubois, Apr. 28 (C. A. Hart and L. M. Smith); Homer, Mar. 30, Apr. 17 (C. A. Hart, J. D. H.); "N. Ill." (A. Bolter). All specimens were taken among fallen oak leaves.

## SYSTEMATIC LIST OF SPECIES.



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# ON THE GENERAL AND INTERIOR DISTRIBUTION OF ILLINOIS FISHES

BY

STEPHEN A. FORBES, PH.D.

ARTICLE III.—*On the General and Interior Distribution of Illinois Fishes.** BY S. A. FORBES.

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The geography of Illinois is, in its most obvious features, so simple and so monotonous that one naturally expects a similar simplicity and monotony in the geographic distribution of its plants and animals. The plan of its hydrography is as little complicated as the geography of its land areas. Surrounded on more than two thirds of its circumference by three large rivers, the Mississippi, the Ohio, and the Wabash, with Lake Michigan covering a narrow strip at its northeast corner and draining a bordering region of scarcely greater area, its other waters flow southwestward into the Mississippi and southward into the Wabash and the Ohio, all mingling finally opposite its southernmost extremity for their journey to the Gulf. Its principal watersheds are inconspicuous ridges or slightly elevated plains, most of them originally more or less marshy, and the headwaters and tributaries of its various stream systems so approach and intermingle that in times of flood they formed an interlacing network, through which it would seem that a wandering fish might have found its way in almost any direction and to almost any place.

Its climate varies considerably, of course, within the five and a half degrees of its length from north to south, but by insensible gradations, with no lines of abrupt transition anywhere to set definite boundaries to the range of its aquatic species.

Its surface geology is more diversified than its topography, and its soils, although uniformly fertile throughout most of the state, differ notably in their origin and physical constitution, some of these differences being such as to affect more or less the surface waters and, through them, to influence the conditions of aquatic life. The extreme northwestern and the extreme southern parts of the state are bare of drift, and their soil is derived immediately from the underlying rock; but the surface of all the remainder of the state, excepting a

*This article is a reprint, with minor changes, of a chapter in the introduction to "The Fishes of Illinois," by S. A. Forbes and R. E. Richardson.

small area above the mouth of the Illinois, has been repeatedly worked over by ice in the course of the successive divisions of the glacial period. The oldest glaciated area, known as the lower Illinoisan glaciation, covers the greater part of southern Illinois and a narrow belt of the southeast part of the central section of the state. Next to this at the northwest, and immediately east of the lower half of the Illinois River, is the middle Illinoisan; above this, in the west-central part of the state, between the Illinois River and the Rock, is the upper Illinoisan; and still farther north, in the Rock River basin, are the Iowan and Preiowan glaciations, reaching northward across the Wisconsin boundary. East of the last three mentioned, and north of the southern Illinois district, the Wisconsin glaciation, the most recent of the series, covers about a fourth of the state. It is to the peculiar features of the lower Illinoisan glaciation especially that we shall presently be compelled to pay particular attention, because of their evident effect on the distribution of a considerable group of our fishes.

The topographical relations of the state to the surrounding territory are as simple and open as its own interior hydrography, and there is little to suggest the possibility of anything in the least peculiar in the general constitution or the relations of its fauna, or anything problematical or especially interesting in the details of the distribution of its native fishes. We shall find reason to believe, however, that this appearance is misleading, and that the subject, studied in detail, contains matter of unusual interest, and presents problems of considerable difficulty, a solution of which will lead us to some novel results.

It is true, however, generally speaking, that the distribution of Illinois fishes reflects, in uniformity and relative monotony, the features of the topography of the state. A few species occurring in Lake Michigan and characteristic of the Great Lakes are, in fact, the only Illinois fishes which are definitely and permanently separated from their fellows in other Illinois waters by what may be called geographical conditions, and these conditions are not physical obstacles to their passage from Lake Michigan to the Illinois River.

Excluding, for the moment, these fishes special to the Great Lakes, we find elsewhere in Illinois a general commingling and overlapping of the fish population of the surrounding territory, the limits to whose range are climatic, local, and ecological, but topographic only in a secondary sense.

## THE GENERAL DISTRIBUTION

Most of the 150 species of the native fishes of Illinois range far and wide in all directions beyond its narrow boundaries, thus illustrating the breadth and the simplicity of our geographical affiliations with the surrounding territory; but a considerable number, on the other hand, coming into Illinois from one direction, do not pass beyond it in another, some part of the boundary of the general area of their distribution passing through our state. Several southern fishes go no farther north than Illinois; some northern fishes go no farther south; some eastern species find here their western limit; and a few western species range no farther east. The comparison of these geographical groups whose areas overlap by their borders here in Illinois is a matter of special interest to the student of distribution, because it is in them that we find indicated the more remote affinities of our fish fauna, and from them, if anywhere, we may glean suggestions of its various origins.

It will be convenient for a discussion of this subject to divide the general expanse over which Illinois fishes are distributed, into the following twelve districts: 1, the upper Mississippi Valley, including the Missouri and its tributaries; 2, the lower Mississippi Valley, including the Ohio and its tributaries; 3, the far North, extending northward from the headwaters of the Mississippi, east to the Lake Superior drainage, and west to the Rocky Mountains; 4, the far Northwest, separated from the preceding by the Rocky Mountains range; 5, the Great Lake region; 6, the district of Quebec and New England; 7, the Hudson River district; 8, the north Atlantic drainage, from New England to the Chesapeake Bay; 9, the south Atlantic, from the Chesapeake Bay to Florida; 10, the peninsula of Florida; 11, the east Gulf district, bounded by the Mississippi drainage on the west; and 12, the west Gulf district, bounded by the Mississippi drainage on the east, and extending west and south to include the Rio Grande and its tributaries. The following table shows the recorded distribution of our species over the territory so divided.

TABLE OF THE GENERAL DISTRIBUTION OF ILLINOIS FISHES

| | Great Lake Basin | Quebec and New England | Hudson River | North Atlantic | South Atlantic | Florida Peninsula | East Gulf | Lower Miss. and Ohio | Upper Miss. and Mo. | West Gulf and Rio Grande | Far Northwest | Far North |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Silvery lamprey (*Ichthyomyzon*)...... | + | + | ... | ... | ... | ... | ... | + | + | ... | ... | ... |
| Brook lamprey (*Lampetra*).......... | + | ... | ... | ... | ... | ... | ... | + | + | ... | ... | ... |
| Paddle-fish (*Polyodon*)............. | + | ... | ... | ... | ... | ... | ... | + | + | ... | ... | ... |
| Lake sturgeon (*Acipenser*).......... | + | + | ... | ... | ... | ... | ... | + | + | ... | ... | + |
| Shovel-nosed sturgeon............ | ... | ... | ... | ... | ... | ... | ... | + | + | + | ... | ... |
| White sturgeon (*P. albus*).......... | ... | ... | ... | ... | ... | ... | ... | + | ... | ... | ... | ... |
| Long-nosed gar.................. | + | + | ... | + | + | + | + | + | + | + | ... | ... |
| Short-nosed gar.................. | + | ... | ... | ... | ... | + | + | + | + | ... | ... | ... |
| Alligator-gar..................... | ... | ... | ... | ... | ... | + | ... | + | + | + | ... | ... |
| Dogfish (*Amia*).................. | + | + | ... | ... | + | + | + | + | + | ... | ... | ... |
| Mooneye (*alosoides*)............. | ... | ... | ... | ... | ... | ... | ... | + | + | ... | ... | + |
| Toothed herring (*tergisus*).......... | + | + | ... | ... | ... | ... | ... | + | + | ... | ... | + |
| Gizzard-shad (*Dorosoma*)........... | + | ... | ... | + | + | + | + | + | + | + | ... | ... |
| Skipjack (*chrysochloris*)............ | + | ... | ... | ... | ... | ... | + | + | + | + | ... | ... |
| Whitefish....................... | + | + | ... | ... | ... | ... | ... | ... | ... | ... | ... | + |
| Lake herring..................... | + | + | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| Lake trout....................... | + | + | ... | ... | ... | ... | ... | ... | ... | ... | + | + |
| Eel............................. | + | + | + | + | + | + | + | + | + | + | ... | ... |
| Black-horse (*Cycleptus*)........... | ... | ... | ... | ... | ... | ... | ... | + | + | + | ... | ... |
| Red-mouth buffalo (*cyprinella*)..... | ... | ... | ... | ... | ... | ... | ... | + | + | ... | ... | + |
| Mongrel buffalo (*urus*)............ | ... | ... | ... | ... | ... | ... | ... | + | + | ... | ... | ... |
| Small-mouth buffalo (*bubalus*)....... | ... | ... | ... | ... | ... | ... | ... | + | + | ... | ... | ... |

TABLE OF THE GENERAL DISTRIBUTION OF ILLINOIS FISHES—*continued*

| | Great Lake Basin | Quebec and New England | Hudson River | North Atlantic | South Atlantic | Florida Peninsula | East Gulf | Lower Miss. and Ohio | Upper Miss. and Mo. | West Gulf and Rio Grande | Far Northwest | Far North |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| River carp (*carpio*) | ... | ... | ... | ... | ... | ... | ... | + | + | + | ... | ... |
| Blunt-nosed carp (*difformis*) | ... | ... | ... | ... | ... | ... | ... | + | + | ... | ... | ... |
| Lake carp (*thompsoni*) | + | + | ... | ... | ... | ... | ... | ... | + | ... | ... | ... |
| Quillback carp (*velifer*) | + | ... | ... | ... | ... | ... | ... | + | + | + | ... | + |
| Chub-sucker | + | + | + | + | + | + | + | + | + | + | ... | ... |
| Striped sucker | + | ... | ... | + | + | ... | + | + | + | + | ... | ... |
| Common sucker (*commersonii*) | + | + | + | + | + | ... | ... | + | + | ... | ... | + |
| Hogsucker (*nigricans*) | + | + | ... | + | + | ... | + | + | + | ... | ... | ... |
| White-nosed sucker (*anisurum*) | + | + | ... | ... | + | ... | ... | + | + | ... | ... | + |
| Common red-horse (*aureolum*) | + | + | + | ... | ... | ... | ... | + | + | ... | ... | + |
| Short-headed red-horse (*breviceps*) | + | ... | ... | ... | ... | ... | ... | + | + | ... | ... | ... |
| *Placopharynx duquesnei* | + | ... | ... | ... | ... | ... | + | + | + | ... | ... | ... |
| Harelipped sucker (*Lagochila*) | + | ... | ... | ... | ... | ... | ... | + | + | ... | ... | ... |
| Stone-roller (*Campostoma*) | + | ... | ... | ... | + | ... | + | + | + | + | ... | ... |
| Red-bellied dace (*Chrosomus*) | + | + | ... | + | + | ... | ... | + | + | ... | ... | ... |
| Silvery minnow (*H. nuchalis*) | ... | ... | ... | + | + | ... | + | + | + | + | ... | + |
| *Hybognathus nubila* | ... | ... | ... | ... | ... | ... | ... | + | + | ... | ... | ... |
| Black-head minnow (*P. promelas*) | + | + | ... | ... | ... | ... | ... | + | + | + | ... | + |
| Blunt-nosed minnow (*P. notatus*) | + | + | ... | + | ... | ... | + | + | + | ... | ... | ... |
| Horned dace (*Semotilus*) | + | + | + | + | + | ... | + | + | + | ... | ... | ... |
| *Opsopæodus emiliæ* | + | ... | ... | ... | + | ... | + | + | + | ... | ... | ... |
| Golden shiner (*Abramis*) | + | + | + | + | + | + | + | + | + | + | ... | ... |

TABLE OF THE GENERAL DISTRIBUTION OF ILLINOIS FISHES—*continued*

| | Great Lake Basin | Quebec and New England | Hudson River | North Atlantic | South Atlantic | Florida Peninsula | East Gulf | Lower Miss. and Ohio | Upper Miss. and Mo. | West Gulf and Rio Grande | Far Northwest | Far North |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Bullhead minnow (*Cliola vigilax*) | + | | | | | | + | + | + | + | | |
| *Notropis anogenus* | + | | | | | | | | + | | | |
| *N. cayuga* | + | | | | | | | + | + | | | + |
| *N. cayuga atrocaudalis* | + | + | | | | | | + | | + | | |
| *N. heterodon* | + | | | | | | | + | + | | | |
| Straw-colored minnow (*N. blennius*) | + | + | | | | | | + | + | + | | + |
| *N. phenacobius* | | | | | | | | | + | | | |
| *N. gilberti* | | | | | | | | | + | | | |
| *N. illecebrosus* | + | | | | | | | + | + | | | |
| Redfin (*N. lutrensis*) | | | | | | | | + | + | + | | |
| Spot-tailed minnow (*N. hudsonius*) | + | + | + | + | + | | | + | + | | | |
| Silverfin (*N. whipplii*) | + | + | | | | | | + | + | | | |
| Common shiner (*N. cornutus*) | + | + | + | + | + | | + | + | + | | | + |
| *Notropis pilsbryi* | | | | | | | | + | + | | | |
| *N. jejunus* | | | | | | | | + | + | | | + |
| Shiner (*N. atherinoides*) | + | + | | | | | | + | + | | | + |
| *Notropis rubrifrons* | + | + | | | + | | | + | + | | | |
| Blackfin (*N. umbratilis atripes*) | + | | | | + | | + | + | + | | | |
| *Ericymba buccata* | + | | | | | | + | + | + | | | |
| Sucker-mouthed minnow (*Phenacobius*) | | | | | | | | + | + | + | | |
| Long-nosed dace (*R. cataractæ*) | + | + | | + | + | | | + | + | + | + | + |

TABLE OF THE GENERAL DISTRIBUTION OF ILLINOIS FISHES—*continued*

| | Great Lake Basin | Quebec and New England | Hudson River | North Atlantic | South Atlantic | Florida Peninsula | East Gulf | Lower Miss. and Ohio | Upper Miss. and Mo. | West Gulf and Rio Grande | Far Northwest | Far North |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Black-nosed dace (*R. atronasus*)...... | + | + | + | + | + | ... | ... | + | + | ... | ... | ... |
| *Hybopsis hyostomus*............... | ... | ... | ... | ... | ... | ... | + | + | + | ... | ... | ... |
| Spotted shiner (*H. dissimilis*)........ | + | ... | ... | ... | ... | ... | ... | + | + | ... | ... | ... |
| Silver chub (*amblops*).............. | + | ... | ... | ... | ... | ... | + | + | + | ... | ... | ... |
| Storer's chub..................... | + | ... | ... | ... | ... | ... | ... | + | + | ... | ... | + |
| River chub (*kentuckiensis*).......... | + | ... | ... | + | + | ... | + | + | + | ... | ... | ... |
| Flat-headed chub (*Platygobio*)....... | ... | ... | ... | ... | ... | ... | ... | + | + | ... | ... | + |
| Blue cat (*furcatus*)............... | ... | ... | ... | ... | ... | ... | ... | + | + | + | ... | ... |
| *Ictalurus anguilla*................ | ... | ... | ... | ... | ... | ... | ... | + | ... | + | ... | ... |
| Channel-cat (*punctatus*)............ | + | ... | ... | ... | ... | + | + | + | + | + | ... | + |
| Great Lake catfish (*lacustris*)........ | + | + | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| Yellow bullhead (*natalis*)........... | + | ... | ... | ... | + | + | + | + | + | + | ... | ... |
| Common bullhead (*nebulosus*)........ | + | + | + | + | + | + | + | + | + | + | ... | + |
| Black bullhead (*melas*)............. | + | ... | ... | ... | ... | ... | + | + | + | ... | ... | ... |
| Mud-cat (*Leptops*)................ | ... | ... | ... | ... | ... | ... | + | + | + | + | ... | ... |
| Common stonecat (*N. flavus*)........ | + | ... | ... | + | ... | ... | ... | + | + | ... | ... | ... |
| Tadpole cat (*S. gyrinus*)........... | + | ... | + | + | ... | + | + | + | + | ... | ... | ... |
| Freckled stonecat (*S. nocturnus*).... | ... | ... | ... | ... | ... | ... | ... | + | + | + | ... | ... |
| Slender stonecat (*S. exilis*).......... | + | ... | ... | ... | ... | ... | ... | + | + | ... | ... | ... |
| Brindled stonecat (*S. miurus*)....... | + | ... | ... | ... | ... | ... | ... | + | + | ... | ... | ... |
| Mud-minnow..................... | + | + | ... | + | ... | ... | ... | + | + | ... | ... | ... |
| Grass pike (*Esox vermiculatus*)....... | + | ... | ... | ... | ... | ... | + | + | + | ... | ... | ... |

TABLE OF THE GENERAL DISTRIBUTION OF ILLINOIS FISHES—*continued*

| | Great Lake Basin | Quebec and New England | Hudson River | North Atlantic | South Atlantic | Florida Peninsula | East Gulf | Lower Miss. and Ohio | Upper Miss. and Mo. | West Gulf and Rio Grande | Far Northwest | Far North |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pike (*E. lucius*) | + | + | ... | + | ... | ... | ... | + | + | ... | + | + |
| Muskallunge | + | + | ... | ... | ... | ... | ... | + | + | ... | ... | + |
| Menona top-minnow (*F. diaphanus m.*) | + | ... | ... | ... | ... | ... | ... | + | + | ... | ... | ... |
| Striped top-minnow (*F. dispar*) | + | ... | ... | ... | ... | ... | + | + | + | ... | ... | ... |
| Common top-minnow (*F. notatus*) | + | ... | ... | ... | ... | ... | + | + | + | + | ... | ... |
| Viviparous top-minnow (*affinis*) | ... | ... | ... | + | + | + | + | + | + | + | ... | ... |
| *Chologaster papilliferus* | ... | ... | ... | ... | ... | ... | ... | ... | + | ... | ... | ... |
| Brook stickleback | + | + | ... | ... | ... | ... | ... | + | + | ... | ... | + |
| Nine-spined stickleback | + | + | + | ... | ... | ... | ... | ... | ... | ... | + | + |
| Trout-perch | + | + | ... | + | ... | ... | ... | + | + | ... | ... | + |
| Brook silverside | + | ... | ... | ... | + | + | + | + | + | ... | ... | ... |
| Pirate-perch | + | ... | ... | + | + | + | + | + | + | ... | ... | ... |
| Pigmy sunfish (*Elassoma*) | ... | ... | ... | ... | + | ... | + | + | ... | ... | ... | ... |
| White crappie (*annularis*) | + | ... | ... | + | + | ... | + | + | + | ... | ... | ... |
| Black crappie (*sparoides*) | + | + | ... | + | + | + | + | + | + | ... | ... | ... |
| Round sunfish | ... | ... | ... | ... | + | + | + | + | ... | ... | ... | ... |
| Rock bass | + | + | + | + | + | ... | + | + | + | ... | ... | + |
| Warmouth (*Chænobryttus*) | + | ... | ... | ... | + | + | + | + | + | + | ... | ... |
| Green sunfish (*cyanellus*) | + | ... | ... | ... | ... | ... | ... | + | + | + | ... | ... |
| *Lepomis ischyrus* | ... | ... | ... | ... | ... | ... | ... | ... | + | ... | ... | ... |
| *L. symmetricus* | ... | ... | ... | ... | ... | ... | ... | + | ... | + | ... | ... |
| *L. euryorus* | + | ... | ... | ... | ... | ... | ... | ... | + | ... | ... | ... |

TABLE OF THE GENERAL DISTRIBUTION OF ILLINOIS FISHES—*continued*

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|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Lepomis miniatus* | ... | ... | ... | ... | ... | + | + | + | + | ... | ... | ... |
| Long-eared sunfish | + | ... | ... | ... | + | + | + | + | + | + | ... | ... |
| Orange-spotted sunfish (*humilis*) | ... | ... | ... | ... | ... | ... | ... | + | + | + | ... | ... |
| Bluegill (*pallidus*) | + | ... | ... | ... | + | + | + | + | + | + | ... | ... |
| *Eupomotis heros* | ... | ... | ... | ... | ... | ... | + | + | ... | + | ... | ... |
| Pumpkinseed (*gibbosus*) | + | + | + | + | + | ... | ... | + | + | ... | ... | ... |
| Small-mouthed black bass | + | + | + | + | + | ... | + | + | + | + | ... | ... |
| Large-mouthed black bass | + | + | + | + | + | + | + | + | + | + | ... | + |
| Pike-perch (*S. vitreum*) | + | + | ... | + | + | ... | + | + | + | ... | ... | + |
| Sauger (*S. canadense griseum*) | + | + | ... | ... | ... | ... | ... | ... | + | ... | ... | + |
| Yellow perch | + | + | + | + | + | ... | ... | + | + | ... | ... | + |
| Log-perch (*P. caprodes*) | + | + | ... | + | ... | ... | + | + | + | + | ... | ... |
| *Hadropterus evermanni* | ... | ... | ... | ... | ... | ... | ... | + | + | ... | ... | ... |
| *H. phoxocephalus* | + | ... | ... | ... | ... | ... | ... | + | + | ... | ... | ... |
| Black-sided darter (*H. aspro*) | + | ... | ... | ... | + | ... | ... | + | + | ... | ... | + |
| *Hadropterus ouachitæ* | ... | ... | ... | ... | ... | ... | ... | + | ... | ... | ... | ... |
| *H. evides* | + | ... | ... | ... | ... | ... | ... | + | + | ... | ... | ... |
| *H. scierus* | ... | ... | ... | ... | ... | ... | ... | + | ... | + | ... | ... |
| *Cottogaster shumardi* | + | ... | ... | ... | ... | ... | ... | + | + | ... | ... | ... |
| Green-sided darter (*blennioides*) | + | ... | ... | ... | ... | ... | + | + | + | ... | ... | ... |
| Johnny darter (*B. nigrum*) | + | + | + | + | + | ... | ... | + | + | ... | ... | + |
| *Boleosoma camurum* | ... | ... | ... | ... | ... | ... | + | + | + | + | ... | ... |

TABLE OF THE GENERAL DISTRIBUTION OF ILLINOIS FISHES—*concluded*

| | Great Lake Basin | Quebec and New England | Hudson River | North Atlantic | South Atlantic | Florida Peninsula | East Gulf | Lower Miss. and Ohio | Upper Miss. and Mo. | West Gulf and Rio Grande | Far Northwest | Far North |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Crystallaria asprella* | + | | | | | | | + | | | | |
| Sand darter (*Ammocrypta*) | + | | | | | | | + | + | + | | |
| Banded darter (*E. zonale*) | + | | | | | | + | + | + | | | |
| Blue-breasted darter (*E. camurum*) | + | | | | | | | + | + | | | |
| *Etheostoma iowæ* | | | | | | | | | + | | | + |
| *E. jessiæ* | + | | | | | | + | + | + | + | | |
| Rainbow darter (*E. cæruleum*) | + | | | + | | | | + | + | + | | |
| *Etheostoma obeyense* | | | | | | | | + | | | | |
| *E. squamiceps* | | | | | | | + | + | | | | |
| Fan-tailed darter (*E. flabellare*) | + | + | | + | + | | | + | + | | | |
| *Boleichthys fusiformis* | + | + | | + | + | + | | + | + | + | | |
| Least darter (*Microperca*) | + | | | + | | | | + | + | | | |
| White bass (*Roccus chrysops*) | + | + | | | | | | + | + | | | |
| Yellow bass (*Morone*) | | | | | | | | + | + | | | |
| Sheepshead (*Aplodinotus*) | + | + | | | | | + | + | + | + | | + |
| Miller's thumb | + | + | | + | + | | + | + | + | | | |
| *Cottus ricei* | + | | | | | | | | | | | |
| *Uranidea kumlienii* | + | | | | | | | | | | | |
| Burbot (*Lota*) | + | + | + | | | | | + | + | | | + |
| Number of species | 108 | 53 | 19 | 40 | 45 | 23 | 56 | 134 | 131 | 47 | 4 | 37 |

Arranged according to the number of Illinois species in each, these districts succeed each other in the following order.

| Districts | No. of species | Per cent. of all Illinois species |
|---|---|---|
| Lower Mississippi and Ohio valleys | 134 | 89 |
| Upper Mississippi and Missouri valleys | 131 | 87 |
| The Great Lake basin | 108 | 72 |
| The east Gulf district | 56 | 37 |
| Quebec and New England | 53 | 36 |
| The west Gulf and Rio Grande district | 47 | 31 |
| The south Atlantic district | 45 | 30 |
| The north Atlantic district | 40 | 27 |
| The far North | 37 | 25 |
| The Florida peninsula | 23 | 15 |
| The Hudson drainage | 19 | 13 |
| The far Northwest | 4 | 3 |

Next to the two Mississippi Valley districts and the Great Lake basin, which average 124 Illinois species, our fishes are most largely represented in the east Gulf and the Quebec and New England districts, averaging 54 Illinois species—the first closely related to the lower Mississippi, and the second a continuation eastward of the Great Lake basin. Then follow the north and south Atlantic and the west Gulf districts, with an average of 43 species; the far North, the Florida peninsula, and the Hudson River districts, with 37 to 19 species; and, finally, the far Northwest, with but 4 Illinois species.

The northern and the southern affiliations of the assemblage of fishes represented in our Illinois collections may be contrasted by comparing the list of Illinois species occurring in either or both of the more northerly divisions—that is, the far North and the Quebec and New England districts—on the one hand, with a list of those found in either or all of the three most southerly districts—that is, the Florida peninsula, the east Gulf, and the west Gulf and Rio Grande—on the other hand. In this northern list of Illinois fishes there are 64 species, and in the southern list there are 77; but 25 of these species are more or less common to both north and south, leaving 39 Illinois fishes distinctively northern in their distribution and 52 distinctively southern. Northern and southern species thus mingle in our territory in unequal proportions, the southern element largely preponderating.

If we look to the further distribution of the northern and southern elements of our fish population, distinguishing northeastern from northwestern species, and southeastern from southwestern, we find that the southeastern species largely outnumber the southwestern in Illinois, and that the northeastern outnumber the northwestern. Thus there are 47 species of the west Gulf and Rio Grande region in this state, and 58 species of the east Gulf and Florida districts.

Further, there are more species known as common to Illinois and the far northeast than there are to Illinois and the southwestern district of the west Gulf and the Rio Grande. Notwithstanding the much greater distance from us of the Quebec and New England district, there are 53 of the fishes of that region known in Illinois to 47 of those of the west Gulf district. The northeastern fishes have, however, been much more carefully collected than the southwestern, and an equal knowledge of both districts might change these relative numbers.

### THE INTERIOR DISTRIBUTION

The interior distribution of the fishes of the state may best be exhibited by treating each considerable stream-system as a unit, and comparing the fishes of each such system with all the others. The state may be conveniently divided into ten such hydrographic districts, as follows:

1. The Galena district, including the streams of the northwestern unglaciated area, most of which empty into the Mississippi through Galena, Apple, and Plum rivers. 2. The Rock River district, extending southward and westward from the northern boundary of the state to the Mississippi at the mouth of the Rock. 3. The Illinois district, including the entire drainage of the Illinois River. 4. The Michigan district, a narrow strip along the borders of Lake Michigan—the Lake Michigan drainage—most of which centers in the Chicago and the Calumet rivers. 5. The Mississippi River, and an irregular strip adjacent not included in any of the more definite river systems and mainly drained by small streams of the bluffs and neighboring highlands. This district is divided by the lower end of the Illinois basin. 6. The Kaskaskia basin. 7. The Illinois drainage of the Wabash, including that stream itself so far as it helps to form the boundary line between Illinois and Indiana. 8. The basin of the Big Muddy River, in the southwestern part of the state.

9. The Saline River basin, in the southeastern part of the state. 10. The Cairo district, the driftless area of extreme southern Illinois, drained by the Cache River and smaller tributaries of the Ohio. The Ohio itself is included in this last district.

The following list and table gives the details of the distribution of the species in a way to show the number of collections of each species made by us from each district. A cross opposite a species name indicates that the species occurs in the basin mentioned at the head of the column, but that it is not represented by preserved collections affording numerical data.

Interior Distribution of Illinois Fishes by River Systems
Species and Number of Collections of each

| | Districts | | | | | | | | | | Sections | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Galena District | Rock River | Illinois River | Michigan Drainage | Mississippi and Creeks | Kaskaskia | Wabash | Big Muddy | Saline | Cairo District | North | Central | South |
| Number of species | 44 | 92 | 128 | 57 | 97 | 69 | 95 | 42 | 55 | 101 | 120 | 123 | 119 |
| Collections made | 13 | 73 | 1115 | 20 | 57 | 41 | 103 | 10 | 18 | 95 | 269 | 1083 | 192 |
| Silvery lamprey | ... | 1 | 12 | 1 | + | .... | 1 | ... | ... | .... | + | + | + |
| Brook lamprey | ... | .... | .... | 1 | .... | .... | .... | ... | ... | 1 | + | 0 | + |
| Paddle-fish | ... | .... | 8 | ... | + | .... | + | ... | ... | 1 | 0 | + | + |
| Lake sturgeon | ... | .... | + | + | + | .... | .... | ... | ... | + | + | + | + |
| Shovel-nosed sturgeon | ... | .... | + | ... | + | .... | + | ... | ... | + | 0 | + | + |
| White sturgeon | ... | .... | .... | ... | 4 | .... | .... | ... | ... | .... | 0 | + | 0 |
| Long-nosed gar | ... | 1 | 20 | 1 | 10 | 1 | + | ... | ... | 4 | + | + | + |

INTERIOR DISTRIBUTION OF ILLINOIS FISHES BY RIVER SYSTEMS
SPECIES AND NUMBER OF COLLECTIONS OF EACH—*continued*

| | Districts | | | | | | | | | | Sections | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Galena District | Rock River | Illinois River | Michigan Drainage | Mississippi and Creeks | Kaskaskia | Wabash | Big Muddy | Saline | Cairo District | North | Central | South |
| Short-nosed gar | ... | 1 | 52 | ... | 4 | + | + | ... | ... | 1 | + | + | + |
| Alligator-gar | ... | ... | + | ... | + | ... | ... | ... | ... | + | 0 | + | + |
| Dogfish | ... | ... | 27 | 1 | 3 | + | 1 | ... | 2 | 1 | + | + | + |
| Mooneye | ... | ... | 1 | ... | + | ... | ... | ... | ... | + | 0 | + | + |
| Toothed herring | ... | ... | 8 | 1 | + | ... | ... | ... | ... | 7 | + | + | + |
| Gizzard-shad | 1 | 3 | 89 | 1 | 1 | 7 | 2 | ... | ... | 3 | + | + | + |
| Skipjack | 2 | 1 | 3 | ... | 2 | ... | ... | ... | ... | + | + | + | + |
| Whitefish | ... | ... | ... | + | ... | ... | ... | ... | ... | ... | + | 0 | 0 |
| Lake herring | ... | ... | ... | + | ... | ... | ... | ... | ... | ... | + | 0 | 0 |
| Lake trout | ... | ... | ... | + | ... | ... | ... | ... | ... | ... | + | 0 | 0 |
| Eel | ... | ... | + | + | + | ... | + | ... | ... | + | + | + | + |
| Black-horse | ... | ... | 1 | ... | 2 | ... | ... | ... | ... | ... | 0 | + | + |
| Red-mouth buffalo | 1 | 1 | 28 | ... | 9 | ... | 2 | ... | ... | 1 | + | + | + |
| Mongrel buffalo | 1 | ... | 17 | 1 | 1 | ... | ... | ... | ... | ... | + | + | + |
| Small-mouth buffalo | 1 | 1 | 46 | 1 | 9 | ... | 2 | ... | ... | + | + | + | + |
| River carp | ... | 1 | 11 | ... | 2 | 1 | + | ... | 1 | + | + | + | + |
| Blunt-nosed carp | 1 | 6 | 54 | ... | 8 | 15 | 21 | ... | 3 | 3 | + | + | + |
| Lake carp | ... | ... | 10 | ... | 1 | ... | ... | ... | ... | ... | + | + | 0 |
| Quillback carp | 1 | 19 | 39 | ... | 1 | 1 | 8 | ... | 1 | + | + | + | + |

INTERIOR DISTRIBUTION OF ILLINOIS FISHES BY RIVER SYSTEMS
SPECIES AND NUMBER OF COLLECTIONS OF EACH—*continued*

| | Districts | | | | | | | | | | Sections | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Galena District | Rock River | Illinois River | Michigan Drainage | Mississippi and Creeks | Kaskaskia | Wabash | Big Muddy | Saline | Cairo District | North | Central | South |
| Chub-sucker | ... | 4 | 48 | ... | 2 | 21 | 47 | 6 | 7 | 10 | + | + | + |
| Striped sucker | 1 | 1 | 13 | 1 | ... | 13 | 16 | 1 | 1 | 3 | + | + | + |
| Common sucker | 1 | 14 | 69 | ... | 9 | 5 | 26 | ... | 3 | 9 | + | + | + |
| Long-nosed sucker | ... | ... | ... | + | ... | ... | ... | ... | ... | ... | + | 0 | 0 |
| Hogsucker | 1 | 11 | 61 | ... | 1 | 9 | 27 | ... | ... | 1 | + | + | + |
| White-nosed sucker | ... | 2 | 14 | + | 1 | ... | ... | ... | ... | ... | + | + | + |
| Common red-horse | 2 | 13 | 90 | ... | 5 | 10 | 25 | ... | 1 | 2 | + | + | + |
| Short-headed red-horse | ... | 4 | 39 | 1 | 3 | 7 | 2 | ... | ... | + | + | + | + |
| *Placopharynx duquesnei* | ... | 1 | 1 | ... | + | ... | 1 | ... | ... | + | + | + | + |
| Harelipped sucker | ... | ... | ... | ... | ... | ... | + | ... | ... | ... | 0 | 0 | + |
| Stone-roller | 1 | 20 | 99 | ... | 14 | 9 | 36 | 1 | 1 | 10 | + | + | + |
| Red-bellied dace | ... | 4 | 13 | ... | 2 | ... | ... | ... | ... | 4 | + | + | + |
| Silvery minnow | 2 | 6 | 86 | 1 | 16 | 10 | 27 | 6 | 11 | 18 | + | + | + |
| *Hybognathus nubila* | 1 | 3 | ... | ... | 1 | ... | ... | ... | ... | 1 | + | + | + |
| Black-head minnow | ... | 8 | 67 | ... | 12 | 6 | 5 | ... | ... | + | + | + | + |
| Blunt-nosed minnow | 3 | 33 | 162 | 3 | 19 | 31 | 77 | 8 | 13 | 25 | + | + | + |
| Horned dace | 1 | 9 | 72 | ... | 16 | 10 | 24 | 4 | 6 | 14 | + | + | + |
| *Opsopœodus emiliæ* | ... | 3 | 49 | 1 | 1 | 1 | 18 | 3 | 6 | 4 | + | + | + |

INTERIOR DISTRIBUTION OF ILLINOIS FISHES BY RIVER SYSTEMS
SPECIES AND NUMBER OF COLLECTIONS OF EACH—*continued*

| | Districts | | | | | | | | | | Sections | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Galena District | Rock River | Illinois River | Michigan Drainage | Mississippi and Creeks | Kaskaskia | Wabash | Big Muddy | Saline | Cairo District | North | Central | South |
| Golden shiner.......... | 1 | 18 | 183 | 1 | 8 | 19 | 50 | 7 | 10 | 10 | + | + | + |
| Bullhead minnow...... | 1 | 14 | 110 | ... | 5 | 22 | 38 | 1 | 3 | 2 | + | + | + |
| *Notropis anogenus*...... | ... | .... | 2 | ... | .... | .... | .... | .... | .... | .... | + | 0 | 0 |
| *Notropis cayuga*........ | 1 | 4 | 29 | 2 | 5 | .... | 1 | .... | ... | 1 | + | + | 0 |
| *N. heterodon*.......... | ... | 5 | 81 | 1 | 1 | .... | 4 | .... | ... | 3 | + | + | + |
| Straw-colored minnow.. | 1 | 22 | 108 | 4 | 9 | 6 | 44 | ... | 2 | 1 | + | + | + |
| *Notropis phenacobius*.... | ... | .... | 2 | ... | .... | .... | .... | .... | .... | .... | + | 0 | 0 |
| *N. gilberti*............. | ... | 3 | 15 | ... | 10 | .... | 2 | .... | .... | .... | + | + | + |
| *N. illecebrosus*......... | ... | .... | 2 | ... | 1 | .... | 17 | .... | ... | + | + | + | + |
| Spot-tailed minnow.... | ... | 4 | 133 | 4 | 4 | .... | .... | .... | ... | 2 | + | + | + |
| Redfin................. | ... | 1 | 142 | 9 | 16 | 4 | .... | 4 | 1 | 10 | + | + | + |
| Silverfin.............. | 3 | 34 | 116 | 1 | 8 | 29 | 71 | 2 | 3 | 6 | + | + | + |
| Common shiner........ | 1 | 19 | 105 | ... | 11 | 14 | 22 | ... | 1 | 12 | + | + | + |
| *Notropis pilsbryi*....... | ... | .... | 1 | ... | .... | .... | .... | .... | .... | .... | + | 0 | 0 |
| *N. jejunus*............ | 1 | 5 | 21 | 1 | 10 | .... | 5 | ... | 2 | 5 | + | + | + |
| Shiner................ | 3 | 8 | 82 | 6 | 8 | 4 | 19 | 4 | 6 | 11 | + | + | + |
| *Notropis rubrifrons*..... | 2 | 4 | 8 | ... | .... | .... | .... | .... | .... | .... | + | + | 0 |
| Blackfin .............. | 2 | 9 | 67 | ... | 3 | 25 | 56 | 5 | 11 | 19 | + | + | + |
| *Ericymba buccata*...... | ... | .... | 4 | ... | .... | 25 | 58 | .... | ... | + | 0 | + | + |

Interior Distribution of Illinois Fishes by River Systems
Species and Number of Collections of each—*continued*

| | Districts | | | | | | | | | | Sections | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Galena District | Rock River | Illinois River | Michigan Drainage | Mississippi and Creeks | Kaskaskia | Wabash | Big Muddy | Saline | Cairo District | North | Central | South |
| Sucker-mouthed minnow | 2 | 15 | 78 | ... | 13 | 17 | 36 | 1 | 4 | 8 | + | + | + |
| Long-nosed dace | ... | ... | ... | ... | ... | ... | ... | ... | ... | 1 | 0 | 0 | + |
| Black-nosed-dace | ... | 1 | 4 | ... | ... | ... | ... | ... | ... | 1 | + | 0 | + |
| *Hybopsis hyostomus* | ... | 2 | 1 | ... | ... | ... | ... | ... | ... | ... | + | + | 0 |
| Spotted shiner | ... | 6 | 3 | ... | ... | 1 | 1 | ... | ... | ... | + | + | + |
| Silver chub | ... | ... | 2 | ... | ... | 10 | 37 | 4 | 2 | ... | 0 | + | + |
| Storer's chub | ... | 1 | 7 | ... | 7 | ... | 5 | ... | 4 | 4 | + | + | + |
| River chub | 1 | 12 | 90 | ... | 8 | 10 | 16 | ... | ... | 1 | + | + | + |
| Flat-headed chub | ... | ... | ... | ... | ... | ... | ... | ... | ... | 3 | 0 | 0 | + |
| Blue cat | ... | ... | 1 | ... | 1 | ... | ... | ... | ... | 2 | 0 | + | + |
| *Ictalurus anguilla* | ... | ... | + | ... | + | ... | ... | ... | ... | + | 0 | + | + |
| Channel-cat | ... | 17 | 108 | ... | 7 | 17 | 26 | 2 | 1 | 2 | + | + | + |
| Great Lake catfish | ... | ... | ... | + | ... | ... | ... | ... | ... | ... | + | 0 | 0 |
| Yellow bullhead | ... | 3 | 82 | ... | ... | 10 | 18 | 3 | 4 | 6 | + | + | + |
| Common bullhead | ... | ... | 42 | ... | 1 | 1 | ... | ... | ... | 4 | + | + | + |
| Black bullhead | 1 | 11 | 144 | ... | 19 | 15 | 35 | 4 | 6 | 10 | + | + | + |
| Mud-cat | + | 3 | 22 | ... | 2 | 1 | 2 | ... | ... | + | + | + | + |
| Stonecat | 2 | 3 | 32 | ... | 1 | 1 | 2 | ... | ... | + | + | + | 0 |
| Tadpole cat | ... | 2 | 132 | ... | 11 | 14 | 21 | 3 | 8 | 5 | + | + | + |

INTERIOR DISTRIBUTION OF ILLINOIS FISHES BY RIVER SYSTEMS
SPECIES AND NUMBER OF COLLECTIONS OF EACH—*continued*

| | Districts | | | | | | | | | | Sections | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Galena District | Rock River | Illinois River | Michigan Drainage | Mississippi and Creeks | Kaskaskia | Wabash | Big Muddy | Saline | Cairo District | North | Central | South |
| Freckled stonecat | ... | ... | 5 | ... | 1 | 2 | + | ... | ... | ... | 0 | + | + |
| Slender stonecat | 1 | ... | 1 | ... | 2 | ... | ... | ... | ... | 2 | + | + | + |
| Brindled stonecat | ... | ... | 1 | ... | ... | 1 | 26 | ... | 5 | 1 | 0 | + | + |
| Mud-minnow | ... | 8 | 18 | 1 | 1 | ... | 4 | 1 | 1 | 6 | + | + | + |
| Grass pike | ... | 5 | 61 | 1 | 4 | 11 | 19 | 7 | 6 | 9 | + | + | + |
| Pike | ... | 2 | 17 | 1 | 1 | ... | ... | ... | ... | 1 | + | + | 0 |
| Muskallunge | ... | ... | + | ... | ... | ... | ... | ... | ... | ... | + | 0 | 0 |
| Menona top-minnow | ... | ... | 11 | 7 | ... | ... | + | ... | ... | ... | + | + | 0 |
| Striped top-minnow | ... | 1 | 75 | 1 | ... | ... | 8 | ... | ... | 5 | + | + | + |
| Common top-minnow | 1 | 6 | 66 | ... | 6 | 23 | 58 | 8 | 17 | 27 | + | + | + |
| Viviparous top-minnow | ... | ... | 1 | ... | 1 | ... | 4 | 1 | 2 | 9 | 0 | + | + |
| *Chologaster papilliferus* | ... | ... | ... | ... | ... | ... | ... | ... | ... | 6 | 0 | 0 | + |
| Brook stickleback | ... | ... | 1 | 2 | ... | ... | ... | ... | ... | ... | + | 0 | 0 |
| Nine-spined stickleback | ... | ... | ... | 1 | ... | ... | ... | ... | ... | ... | + | 0 | 0 |
| Trout-perch | ... | ... | 14 | 1 | ... | ... | ... | ... | ... | ... | + | + | 0 |
| Brook silverside | 1 | 6 | 89 | 2 | 2 | 1 | 21 | ... | ... | ... | + | + | + |
| Pirate-perch | ... | ... | 54 | ... | ... | 9 | 11 | 7 | 11 | 9 | + | + | + |
| Pigmy sunfish | ... | ... | ... | ... | ... | ... | 5 | ... | ... | 1 | 0 | 0 | + |

Interior Distribution of Illinois Fishes by River Systems
Species and Number of Collections of each—*continued*

| | Districts | | | | | | | | | | Sections | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Galena District | Rock River | Illinois River | Michigan Drainage | Mississippi and Creeks | Kaskaskia | Wabash | Big Muddy | Saline | Cairo District | North | Central | South |
| White crappie | 2 | 9 | 119 | 2 | 13 | 6 | 14 | 3 | 3 | 6 | + | + | + |
| Black crappie | ... | 8 | 130 | 3 | 15 | 8 | 13 | 3 | 1 | ... | + | + | + |
| Round sunfish | ... | ... | 1 | ... | ... | ... | 1 | 1 | 2 | 8 | 0 | 0 | + |
| Rock bass | ... | 4 | 35 | 1 | 3 | 2 | 1 | 1 | ... | 2 | + | + | + |
| Warmouth | ... | 3 | 83 | ... | 3 | 5 | 10 | 6 | 6 | 11 | + | + | + |
| Green sunfish | 2 | 20 | 158 | ... | 16 | 33 | 57 | 7 | 12 | 15 | + | + | + |
| *Lepomis ischyrus* | ... | 1 | 3 | ... | ... | ... | ... | ... | ... | ... | + | + | 0 |
| *L. symmetricus* | ... | ... | 2 | ... | ... | ... | 3 | ... | ... | 4 | 0 | + | + |
| *L. euryorus* | ... | ... | 1 | ... | ... | ... | ... | ... | ... | ... | 0 | + | 0 |
| *L. miniatus* | ... | ... | 24 | ... | 1 | ... | 2 | ... | ... | ... | + | + | + |
| Long-eared sunfish | ... | 3 | 37 | 1 | ... | 27 | 57 | 7 | 8 | 16 | + | + | + |
| Orange-spotted sunfish | ... | 5 | 112 | ... | 22 | 15 | 23 | 2 | 3 | 3 | + | + | + |
| Bluegill | 2 | 7 | 179 | 1 | 6 | 3 | 18 | 1 | 1 | 6 | + | + | + |
| *Eupomotis heros* | ... | ... | ... | ... | ... | ... | 5 | ... | ... | 1 | 0 | 0 | + |
| Pumpkinseed | ... | 4 | 82 | 4 | 2 | ... | 1 | ... | ... | 1 | + | + | + |
| Small-mouthed black bass | ... | 16 | 69 | ... | 5 | 2 | 8 | 1 | ... | 3 | + | + | + |
| Large-mouthed black bass | ... | 7 | 135 | 4 | 13 | 8 | 33 | 2 | 4 | 12 | + | + | + |
| Pike-perch | ... | 3 | 20 | 1 | 13 | 1 | + | ... | ... | ... | + | + | + |

INTERIOR DISTRIBUTION OF ILLINOIS FISHES BY RIVER SYSTEMS
SPECIES AND NUMBER OF COLLECTIONS OF EACH—*concluded*

| | Districts | | | | | | | | | | Sections | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Galena District | Rock River | Illinois River | Michigan Drainage | Mississippi and Creeks | Kaskaskia | Wabash | Big Muddy | Saline | Cairo District | North | Central | South |
| Sauger | ... | 1 | 13 | ... | 3 | 1 | .... | ... | ... | .... | + | + | 0 |
| Yellow perch | ... | + | 75 | 3 | 6 | .... | .... | ... | ... | .... | + | + | 0 |
| Log-perch | ... | 4 | 35 | 3 | 5 | 9 | 8 | ... | 1 | 2 | + | + | + |
| *Hadropterus evermanni* | ... | .... | 3 | ... | .... | .... | .... | ... | ... | .... | 0 | + | 0 |
| *H. phoxocephalus* | ... | 12 | 58 | ... | 3 | 10 | 6 | ... | 2 | .... | + | + | + |
| Black-sided darter | 2 | 15 | 70 | ... | 1 | 22 | 42 | 2 | 7 | 11 | + | + | + |
| *Hadropterus ouachitæ* | ... | .... | .... | ... | .... | .... | 1 | ... | ... | .... | 0 | 0 | + |
| *H. evides* | ... | 1 | .... | ... | .... | .... | .... | ... | ... | .... | + | 0 | 0 |
| *H. scierus* | ... | .... | 1 | ... | .... | .... | 1 | ... | ... | .... | 0 | + | 0 |
| *Cottogaster shumardi* | ... | .... | 14 | ... | .... | 2 | 1 | ... | ... | .... | 0 | + | + |
| Green-sided darter | ... | .... | + | ... | .... | .... | 36 | ... | ... | .... | 0 | + | + |
| Johnny darter | 3 | 22 | 100 | 3 | 10 | 27 | 58 | 1 | 6 | 8 | + | + | + |
| *Boleosoma camurum* | ... | 1 | 45 | 2 | 2 | 12 | 17 | 7 | 11 | 10 | + | + | + |
| *Crystallaria asprella* | 1 | 3 | .... | ... | 2 | .... | 1 | ... | ... | .... | + | + | + |
| Sand darter | ... | 3 | 7 | ... | 1 | 2 | 16 | ... | ... | .... | + | + | + |
| Banded darter | 1 | 11 | 21 | ... | .... | .... | 1 | ... | ... | .... | + | + | + |
| Blue-breasted darter | ... | 2 | 6 | 1 | .... | .... | .... | ... | ... | 1 | 0 | + | 0 |
| *Etheostoma iowæ* | ... | 2 | 4 | 1 | .... | .... | .... | ... | ... | 1 | + | 0 | + |
| *E. jessiæ* | ... | 4 | 119 | ... | 5 | 11 | 14 | 2 | 1 | 4 | + | + | + |

INTERIOR DISTRIBUTION OF ILLINOIS FISHES BY RIVER SYSTEMS
SPECIES AND NUMBER OF COLLECTIONS OF EACH—*concluded*

| | Districts | | | | | | | | | | Sections | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Galena District | Rock River | Illinois River | Michigan Drainage | Mississippi and Creeks | Kaskaskia | Wabash | Big Muddy | Saline | Cairo District | North | Central | South |
| Rainbow darter | 2 | 9 | 39 | ... | 1 | 2 | 29 | 1 | 4 | 13 | + | + | + |
| *Etheostoma obeyense* | ... | ... | ... | ... | ... | ... | ... | ... | 1 | ... | 0 | 0 | + |
| *E. squamiceps* | ... | ... | ... | ... | ... | 1 | 1 | ... | 1 | 7 | 0 | + | + |
| Fan-tailed darter | 1 | 6 | 11 | ... | 1 | 1 | 14 | ... | ... | 3 | + | + | + |
| *Boleichthys fusiformis* | ... | 1 | 13 | ... | ... | 5 | 18 | 3 | 8 | 8 | + | + | + |
| Least darter | ... | 1 | 10 | ... | ... | ... | ... | ... | ... | 1 | + | 0 | + |
| White bass | 1 | 2 | 36 | 2 | 12 | ... | ... | ... | ... | 1 | + | + | + |
| Yellow bass | ... | 1 | 95 | ... | 5 | ... | ... | ... | ... | ... | + | + | + |
| Sheepshead | ... | 1 | 53 | ... | 13 | ... | ... | 1 | 1 | 1 | + | + | + |
| Miller's thumb | ... | ... | 5 | ... | ... | ... | ... | ... | ... | 6 | + | + | + |
| *Cottus ricei* | ... | ... | ... | + | ... | ... | ... | ... | ... | ... | + | 0 | 0 |
| *Uranidea kumlienii* | ... | ... | ... | + | ... | ... | ... | ... | ... | ... | + | 0 | 0 |
| Burbot | ... | ... | 3 | 1 | ... | ... | ... | ... | ... | ... | + | + | 0 |

### THE ILLINOIS BASIN AND THE OTHER DISTRICTS COMPARED

The key to the distribution of Illinois fishes within the state is the species list of the Illinois basin. Covering fully one half the area of Illinois, and extending in a broad belt diagonally northeast and southwest across its northern two thirds, this basin contains nearly every variety of stream, lake, pond, and marsh to be found between the

Great Lakes on the one hand and the giant flood of the Mississippi on the other, and it is to be expected that its fish population will be highly typical of Illinois as a whole. It includes, in fact, more than four fifths of the species on our Illinois list, and the special features of the various other basins and areas may best be seen by comparing them with this characteristic central basin as a type.

The following is a list of the species of the Illinois system obtained by us in collections, arranged in the order of the frequency of their appearance in 1,115 collections made from that stream and its tributary waters.

Species of the Illinois Basin, and Number of Collections containing each

| Species | Collections | Species | Collections* |
|---|---|---|---|
| Golden shiner | 183 | Common red-horse | 90 |
| Bluegill | 179 | Gizzard-shad | 89 |
| Blunt-nosed minnow | 162 | Brook silverside | 89 |
| Green sunfish | 158 | Silvery minnow | 86 |
| Black bullhead | 144 | Warmouth | 83 |
| Redfin (*lutrensis*) | 142 | Shiner | 82 |
| Large-mouthed black bass | 135 | Yellow bullhead | 82 |
| Spot-tailed minnow | 133 | Pumpkinseed | 82 |
| Tadpole cat | 132 | *Notropis heterodon* | 81 |
| Black crappie | 130 | Sucker-mouthed minnow | 78 |
| *Etheostoma jessiæ* | 119 | Yellow perch | 75 |
| White crappie | 119 | Striped top-minnow | 75 |
| Silverfin | 116 | Horned dace | 72 |
| Orange-spotted sunfish | 112 | Black-sided darter | 70 |
| Bullhead minnow | 110 | Common sucker | 69 |
| Straw-colored minnow | 108 | Small-mouthed black bass | 69 |

*A cross (+) in this column indicates the known occurrence of a species which is not represented in our collections from the Illinois basin.

Species of the Illinois Basin, and Number of Collections containing each—*continued*

| Species | Collections | Species | Collections |
|---|---|---|---|
| Channel-cat | 108 | Blackfin | 67 |
| Common shiner | 105 | Black-head minnow | 67 |
| Johnny darter | 100 | Common top-minnow | 66 |
| Stone-roller | 99 | Hogsucker | 61 |
| Yellow bass | 95 | Grass pike | 61 |
| River chub | 90 | *Hadropterus phoxocephalus* | 58 |
| Blunt-nosed carp | 54 | Pike | 17 |
| Pirate-perch | 54 | *Notropis gilberti* | 15 |
| Sheepshead | 53 | White-nosed sucker | 14 |
| Short-nosed gar | 52 | Trout-perch | 14 |
| *Opsopœodus emiliæ* | 49 | *Cottogaster shumardi* | 14 |
| Chub-sucker | 48 | Striped sucker | 13 |
| Small-mouth buffalo | 46 | Red-bellied dace | 13 |
| *Boleosoma camurum* | 45 | Sauger | 13 |
| Common bullhead | 42 | *Boleichthys fusiformis* | 13 |
| Quillback carp | 39 | Silvery lamprey | 12 |
| Rainbow darter | 39 | Menona top-minnow | 11 |
| Short-headed red-horse | 39 | Fan-tailed darter | 11 |
| Long-eared sunfish | 37 | River carp | 11 |
| White bass | 36 | Least darter | 10 |
| Rock bass | 35 | Lake carp | 10 |
| Log-perch | 35 | Paddle-fish | 8 |
| Stonecat | 32 | Toothed herring | 8 |
| *Notropis cayuga* | 29 | *Notropis rubrifrons* | 8 |
| Red-mouth buffalo | 28 | Storer's chub | 7 |

SPECIES OF THE ILLINOIS BASIN, AND NUMBER OF COLLECTIONS CONTAINING EACH—*concluded*

| Species | Collections | Species | Collections |
|---|---|---|---|
| Dogfish | 27 | Sand darter | 7 |
| *Lepomis miniatus* | 24 | Blue-breasted darter | 6 |
| Mud-cat | 22 | Freckled stonecat | 5 |
| *Notropis jejunus* | 21 | Miller's thumb | 5 |
| Banded darter | 21 | Black-nosed dace | 4 |
| Long-nosed gar | 20 | *Ericymba buccata* | 4 |
| Pike-perch | 20 | Skipjack | 3 |
| Mud-minnow | 18 | Spotted shiner | 3 |
| Mongrel buffalo | 17 | *Lepomis ischyrus* | 3 |
| *Hadropterus evermanni* | 3 | Brindled stonecat | 1 |
| Burbot | 3 | Slender stonecat | 1 |
| *Notropis phenacobius* | 2 | Brook stickleback | 1 |
| Silver chub | 2 | Round sunfish | 1 |
| *Lepomis symmetricus* | 2 | *Lepomis euryorus* | 1 |
| *Notropis anogenus* | 2 | *Hadropterus scierus* | 1 |
| *N. illecebrosus* | 2 | Lake sturgeon | + |
| Viviparous top-minnow | 1 | Shovel-nosed sturgeon | + |
| Mooneye | 1 | Alligator-gar | + |
| Black-horse | 1 | Eel | + |
| *Placopharynx duquesnei* | 1 | *Ictalurus anguilla* | + |
| *Notropis pilsbryi* | 1 | Muskallunge | + |
| *Hybopsis hyostomus* | 1 | Green-sided darter | + |
| Blue cat | 1 | | |

Of the twenty-three Illinois species which have not been taken by us in the Illinois River or its tributaries, two are distinctively western fishes, and occur but rarely anywhere within our limits; nine are southern species, few of which have been found as far north as the mouth of the Illinois, and one other is only southern in this state; two are northern species which barely reach our borders; five are typical fishes of the Great Lakes; one has been found by us only in the main Mississippi and the Ohio; one is a subterranean fish of strictly local occurrence; and the two remaining species are very rare in this state.

Further particulars as to the species of these various geographical groups are given in the following classified list.

ILLINOIS SPECIES NOT FOUND IN THE ILLINOIS BASIN

WESTERN (2):
*Hybognathus nubila*
Flat-headed chub

SOUTHERN (10):
Harelipped sucker
Pigmy sunfish
Round sunfish
*Eupomotis heros*
*Hadropterus ouachitæ*
*H. evides*
*Crystallaria asprella*
*Etheostoma obeyense*
*E. squamiceps*
Brindled stonecat

GREAT LAKES (5):
Whitefish
Lake herring
Lake trout
*Cottus ricei*
*Uranidea kumlienii*

NORTHERN (2):
Long-nosed sucker
Nine-spined stickleback

MAIN MISSISSIPPI (1):
White sturgeon

SUBTERRANEAN (1):
*Chologaster papilliferus*

RARE IN ILLINOIS (2):
Brook lamprey
Long-nosed dace

As the Illinois basin contains 128 of the 150 species taken by us in the state, it is evident that the other and smaller basins must differ from this negatively rather than positively. Being not only much smaller, but also much less complex than the Illinois district, and offering less variety of situations for fishes as homes and places of resort, they may lack many species which find a fit environment somewhere in the Illinois or its dependent waters, but can contain relatively few not found there as well.

Regarded from this standpoint, the Michigan district is farthest removed from the Illinois ichthyologically, and of its fifty-seven species nine (16 per cent.) are wanting in the Illinois basin. The Cairo district differs much less, eight of its one hundred and one fishes being without representation in our collections from the Illinois system. Next follows the Wabash basin in Illinois, with ninety-five species and a difference from the Illinois basin of 6.1 per cent.; the Galena district, with forty-four species and a difference of 4.6 per cent.; the Saline district, with fifty-five species, and a difference of 3.8 per cent.; and the Mississippi and its marginal area, with ninety-seven species, 3.2 per cent. of which are wanting to the Illinois streams and lakes. The Kaskaskia and the Big Muddy, on the other hand, which are scarcely more than extensions of the Illinois district downward to the southern end of the state, contain virtually no fishes not in the main district, the Kaskaskia but one out of sixty-nine (1.4 per cent.), and the Big Muddy none out of forty-two species. The Rock River district differs from the Illinois by only three species out of ninety-two (3.2 per cent.). These data are presented more compactly in the table following.

Differences between the Smaller Districts and the Illinois Basin

| Districts | Species in district | Species not found in Illinois basin | Ratios of difference |
|---|---|---|---|
| Illinois | 128 | —— | —— |
| Michigan | 57 | 9 | .16 |
| Cairo | 101 | 8 | .08 |
| Wabash | 95 | 6 | .061 |
| Galena | 44 | 2 | .046 |
| Saline | 55 | 2 | .038 |
| Mississippi | 97 | 3 | .032 |
| Rock River | 92 | 3 | .032 |
| Kaskaskia | 69 | 1 | .014 |
| Big Muddy | 42 | 0 | .000 |

Five species were found in the Illinois system and not in any other—three of them minnows of the genus *Notropis* (*anogenus*, *phenacobius*, and *pilsbryi*), one of them a sunfish (*Lepomis euryorus*), and one of them a darter (*Hadropterus evermanni*). All of these species have been very rare in our collections, occurring only from one to three times each, and it was probable that they would be found, if at all, where the largest number of collections was made.

The Galena district is distinguished from the Illinois basin especially by the presence of a minnow and a darter (*Hybognathus nubila* and *Crystallaria asprella*), the latter southern in its main range, and the former western, not occurring, indeed, farther east than western Illinois. These two fishes appear in the Rock River basin also, together with another distinctively western darter (*Hadropterus evides*). In the Michigan district, besides the five lake fishes already referred to—the whitefish, the lake herring, the lake trout, and two cottoids or miller's thumbs, *Cottus ricei* and *Uranidea kumlienii*—are the brook lamprey, the long-nosed sucker, the Great Lake catfish, and one of the sticklebacks (*Pygosteus pungitius*). All but the lamprey (which is rare in Illinois) are northern species not taken by us in the Illinois valley. The Mississippi district is distinguished from the Illinois by the presence of the rare white sturgeon (*Parascaphirhynchus albus*), hitherto taken only in the Mississippi itself, and by a southern darter and a western minnow already referred to. In the Kaskaskia district we find another southern darter (*Etheostoma squamiceps*). The six fishes of the Wabash district not found in the Illinois or its tributaries, are all southern species. The Big Muddy list contains no species not found in the Illinois basin; and the Saline River district contains two southern darters (*Etheostoma squamiceps* and *E. obeyense*). And, finally, among the eight species by which the Cairo district differs from the Illinois are three southern and two western species, a cave-fish, and two species of general distribution but rare in Illinois (*Lampetra wilderi* and *Rhinichthys cataractæ*).

Thus, of the twenty-three Illinois fishes not found by us in the waters of the Illinois basin, eight are distinctively southern, six are purely northern, if we include in this number the Great Lake fishes, four are western, one is an extremely local cave-fish, and four are so rare in Illinois that their appearance in any waters is a matter of unusual chance. The limitation upon the range of these imperfectly distributed species is thus climatic and general, and not geographic or local. This state lies on the extreme borders of their proper territory, and they are not found more commonly in our waters because climatic and other general conditions most favorable to their maintenance, here reach the vanishing point.

LISTS OF SPECIES DISTINGUISHING DIFFERENT DISTRICTS FROM THE ILLINOIS BASIN

GALENA DISTRICT (2):
*Hybognathus nubila* (Western)
*Crystallaria asprella* (Southern)

ROCK RIVER DISTRICT (3):
*Hybognathus nubila* (Western)
*Hadropterus evides* (Western)
*Crystallaria asprella* (Southern)

MICHIGAN DISTRICT (9):
Brook lamprey (rare)
Long-nosed sucker (Northern)
Whitefish (Great Lakes)
Lake herring (Great Lakes)
Lake trout (Great Lakes)
Great Lake catfish (Northern)
Nine-spined stickleback (Northern)
*Cottus ricei* (Great Lakes)
*Uranidea kumlienii* (Great Lakes)

MISSISSIPPI STRIP (3):
White sturgeon (rare; Mississippi only)
*Hybognathus nubila* (Western)
*Crystallaria asprella* (Southern)

KASKASKIA RIVER DISTRICT (1):
*Etheostoma squamiceps* (Southern)

WABASH DISTRICT (6):
Harelipped sucker (rare; Southern)
Pigmy sunfish (Southern)
*Eupomotis heros* (Southern)
*Hadropterus ouachitæ* (Southern)
*Crystallaria asprella* (Southern)
*Etheostoma squamiceps* (Southern)

SALINE RIVER DISTRICT (2):
*Etheostoma obeyense* (Southern)
*E. squamiceps* (Southern)

CAIRO DISTRICT (8):
Brook lamprey
*Hybognathus nubila* (Western)
Long-nosed dace (rare in Illinois)
Flat-headed chub (Western)
*Chologaster papilliferus* (subterranean)
Pigmy sunfish (Southern)
*Eupomotis heros* (Southern)
*Etheostoma squamiceps* (Southern)

RELATIONS OF EACH DISTRICT TO ALL THE OTHERS

In the foregoing discussions and analyses the fishes of the various districts have been compared with those of the largest and most central district as a type; but a fuller and more accurate idea of the composition of the fish population of Illinois and of its relations in the various hydrographic divisions of the state may be obtained by a comparison of the species of each of our ten districts successively with those of all the others. This may be done in an exact and uniform manner by determining for each pair of districts the ratio which the number of species common to the pair bears to the whole number of species occurring within the area of both the districts taken together as one. In the Galena district, for example, there are 44 species recorded, and in the Saline River basin there are 55, a total of 99; but as 26 of these species have been found in both these districts, this number has been taken twice in the above addition, and the number of species found by us in the entire area of these two districts is consequently 73. The ichthyological affinity of these two areas is evidently to be measured by the ratio which the number of species common to both bears to the whole number of species found in either or both the areas—in this case, the ratio of 26 to 73, or 36 per cent. That is, 36 per cent. of the fishes found in either of these two districts have been found by us in both of them.

A similar analysis of the data for each of the forty-five pairs which it is possible to make up from our ten hydrographic districts, yields the material for the following table of common species and of ratios of affiliation. This table shows, in the lower left-hand part,

Number of Species Common to each Pair of Districts, and Ratios of such Common Numbers to the whole Number of Species in each Pair

| Districts | 1. Galena | 2. Rock River | 3. Illinois R. | 4. Michigan | 5. Mississippi | 6. Kaskaskia | 7. Wabash | 8. Big Muddy | 9. Saline | 10. Cairo | Averages |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. Galena | .... | 45 | 32 | 20 | 41 | 40 | 38 | 28 | 36 | 37 | .352 |
| 2. Rock River | 42 | .... | 68 | 35 | 69 | 59 | 63 | 40 | 47 | 62 | .542 |
| 3. Illinois River | 42 | 89 | .... | 35 | 72 | 53 | 66 | 33 | 41 | 68 | .52 |
| 4. Michigan | 17 | 39 | 48 | .... | 34 | 25 | 29 | 22 | 23 | 32 | .283 |
| 5. Mississippi | 41 | 77 | 94 | 39 | .... | 54 | 61 | 34 | 42 | 66 | .525 |
| 6. Kaskaskia | 32 | 60 | 68 | 25 | 58 | .... | 66 | 52 | 63 | 53 | .517 |
| 7. Wabash | 38 | 72 | 89 | 34 | 73 | 66 | .... | 41 | 53 | 63 | .534 |
| 8. Big Muddy | 19 | 38 | 42 | 18 | 35 | 38 | 40 | .... | 70 | 39 | .398 |
| 9. Saline River | 26 | 47 | 53 | 21 | 45 | 48 | 52 | 40 | .... | 49 | .471 |
| 10. Cairo | 39 | 74 | 93 | 38 | 79 | 59 | 76 | 40 | 51 | .... | .521 |
| Total species | 44 | 92 | 128 | 57 | 97 | 69 | 95 | 42 | 55 | 101 | |
| Number of collections | 13 | 73 | 1115 | 20 | 57 | 41 | 103 | 10 | 18 | 95 | |

the number of species common to each pair of districts, and in the upper right-hand part the ratios which these numbers bear to the number of species occurring in each pair of districts taken as one. The number of species common to any two districts will be found in the lower left-hand part of the table, where the column for one district intersects with the line for the other, and the ratio of affiliation for the same pair of districts will be found in the opposite part of the table at the intersection of the line for the first with the column for the second. A simple inspection of the figures in the latter part shows at once which districts are most alike and which are most unlike in respect to their fish inhabitants. Thus, the Rock and Illinois basins and the Mississippi are the most closely related, according to these data, with affiliation ratios of 68–72 per cent. and an average of 70; and the Michigan, Galena, and Big Muddy districts are the least alike, with ratios of 20–28 per cent. and an average of 23. The two highest single ratios of ichthyological affiliation are those of the Illinois and Mississippi rivers (.72) and of the Big Muddy and Saline (.70).

The data of this table may be generalized by bringing into comparison the *average* of the ratios of affiliation for each district with those for all the rest, as shown in the column of figures farthest to the right. If the ten districts are arranged in the order of the size of their average ratios, they readily fall into two groups, the first of six districts, with relatively high ratios, and the second of four, with relatively low ratios. The first group comprises the basins of the larger rivers—the Mississippi, the Rock, the Illinois, the Kaskaskia, the Wabash, and the Ohio, each with its more or less complex system of tributaries. The average ratio for this group is 52.7 per cent. The second group is made up of small, widely separated districts, containing only small streams and lakes, except that one of them includes a little of the shallow southwestern border of Lake Michigan. In this group are the northwestern driftless area, the Saline River and its tributaries, the Big Muddy district, and the Michigan district, with an average affiliation ratio of 37.6.

If we average separately, for these groups, the ratios of each district to all the other districts of its group, we obtain for the first and higher group a ratio of mutual affiliation of 63 per cent., and for the lower group a similar ratio of 33 per cent. It is thus made clear that the districts most typical of our Illinois fauna are the first six above mentioned, while those most individual and peculiar—least closely affiliated among themselves and each with all the others—are the Michigan, the Galena, the Saline, and the Big Muddy districts, excepting only the relation of the two last mentioned, which, as already said, is unusually close.

### THE FISHES OF NORTHERN, CENTRAL, AND SOUTHERN ILLINOIS

If mere difference in latitude, involving a climatic difference within a range of five and a half degrees, limits the distribution of any of our fishes, the fact should appear upon a comparison of the species list of the northern, central, and southern sections of the state, although due caution must, of course, be exercised that other and more local causes are not confused with climatic ones. The division of the state here adopted, is shown on Map I. of the accompanying set.

The fishes of these three divisions number 119 species for northern, 123 for central, and 119 for southern Illinois, respectively. Fourteen species have been found by us only in the northern division, 9 only in the southern, and 5 only in the central, and 89 species are found in all three sections. Twelve species occur in both northern and central Illinois, but not in southern, 17 in both southern and central Illinois, but not in northern, and 4 in both the northern and southern divisions of the state, but not in the central.

FISHES OF LIMITED DISTRIBUTION IN ILLINOIS

| Illinois Distribution | General Distribution |
|---|---|
| Species Peculiar to Northern Illinois | |
| Whitefish | Great Lakes |
| Lake herring | " " |
| Lake trout | " " |
| Long-nosed sucker | Northern |
| *Notropis anogenus* | " |
| *N. phenacobius* | |
| *N. pilsbryi* | Southern |
| Great Lake catfish | Northern |
| Muskallunge | " |
| Brook stickleback | " |
| Nine-spined stickleback | " |
| *Hadropterus evides* | Rather general |
| *Cottus ricei* | Great Lakes |
| *Uranidea kumlienii* | " " |
| Species Peculiar to Southern Illinois | |
| Harelipped sucker | Southern |
| Long-nosed dace | General; rare in Illinois |
| Flat-headed chub | Western |
| *Chologaster papilliferus* | Local; cave |
| Pigmy sunfish | Southern |
| Round sunfish | " |
| *Eupomotis heros* | " |
| *Hadropterus ouachitæ* | " |
| *Etheostoma obeyense* | " |

FISHES OF LIMITED DISTRIBUTION IN ILLINOIS—*concluded*

| Illinois Distribution | General Distribution |
| --- | --- |
| Species in Northern and Central Illinois, but not in Southern | |
| Lake carp | Northern |
| *Notropis cayuga* | General |
| *N. rubrifrons* | " |
| *Hybopsis hyostomus* | " |
| Stonecat | Northern and southwestern |
| Pike | Northern |
| Menona top-minnow | " |
| Trout-perch | " |
| *Lepomis ischyrus* | |
| Sauger | General |
| Yellow perch | Northern |
| Burbot | Great Lakes |
| Species in Southern and Central Illinois, but not in Northern | |
| Paddle-fish | General |
| Shovel-nosed sturgeon | " |
| Alligator-gar | Southern |
| Mooneye | Northern |
| Black-horse | General |
| *Ericymba buccata* | " |
| Silver chub | " |
| Blue cat | Southern |
| *Ictalurus anguilla* | " |
| Freckled stonecat | " |
| Brindled stonecat | General |

FISHES OF LIMITED DISTRIBUTION IN ILLINOIS—*concluded*

| Illinois Distribution | General Distribution |
|---|---|
| Viviparous top-minnow | Southern |
| *Lepomis symmetricus* | " |
| *Cottogaster shumardi* | General |
| Green-sided darter | " |
| *Etheostoma squamiceps* | Southern |

An examination of the general distribution of the species of these sectional lists of Illinois fishes shows, as was to have been expected, that the distinctively northern Illinois fishes are chiefly northern in their outside range, and that those of southern Illinois are mainly southern. Thus, of the 14 especially northern Illinois fishes, 11 are northerly in their general distribution and 1 is southerly; while of the 9 distinctively southern Illinois species, 6 are southerly in their general range, 1 is western, and 1 is a cave-fish local to Illinois. The species found in the northern and central sections of the state and not in the southern are varied in their distribution, 6 of them ranging northward from Illinois, and 4 of them in all directions, while 1 has been thus far found in Illinois only. The central and southern fishes, on the other hand, comprise 7 southern species, 1 of northern and 8 of general range, and 1 whose distribution is not recorded. Including only species whose general area shows that their restricted occurrence in Illinois is a feature of their geographical distribution at large, and excluding fishes special to the Great Lakes, we have twenty-six species whose distribution in this state seems limited by conditions connected with differences in latitude merely—twelve of these species essentially northern and fourteen of them southern.

Especially Northern Species in Illinois (16):

- Whitefish
- Lake herring
- Lake trout
- Long-nosed sucker
- Lake carp
- *Notropis anogenus*
- Great Lake catfish
- Mooneye
- Pike
- Muskallunge
- Menona top-minnow
- Brook stickleback
- Nine-spined stickleback
- Trout-perch
- *Cottus ricei*
- *Uranidea kumlienii*

Especially Southern Species in Illinois (14):

- Alligator-gar
- Blue cat
- *Ictalurus anguilla*
- Freckled stonecat
- Harelipped sucker
- *Notropis pilsbryi*
- Viviparous top-minnow
- Pigmy sunfish
- Round sunfish
- *Lepomis symmetricus*
- *Eupomotis heros*
- *Hadropterus ouachitæ*
- *Etheostoma obeyense*
- *E. squamiceps*

### USE OF LOCALITY MAPS

In the foregoing discussion of the sectional distribution of Illinois fishes no account has been taken of differences in the frequency of the occurrence of the species in the different sections in which they have been found, a single occurrence in southern Illinois, for example, counting for as much as fifty such occurrences in the northern part of the state. That highly interesting and important peculiarities of distribution are concealed by this gross method of comparison is made evident by an examination of the maps of the distribution of our collections of the various species accompanying this report, where the data are presented in a way to show, not the number of collections, it is true, in which each species was represented, but the number and distribution of localities from which the species has been obtained. From such a study of these maps it appears that the northern half or two thirds of this state is more favorable to a considerable number of species than the southern part, since these species have been taken there in a much larger number of localities; and also that a small group of species of wide general distribution has been found by us with surprising frequency in the Wabash drainage in this state as compared with that of adjacent districts.

The preference of certain species for the northern part of Illinois over the southern is clearly illustrated by the distribution maps of the following fifteen species: *Noturus flavus*, *Carpiodes thompsoni*, *Notropis cayuga*, *N. hudsonius*, *N. rubrifrons*, *Hybopsis dissimilis*, *H. kentuckiensis*, *Fundulus diaphanus*, *Percopsis guttatus*, *Eupomotis* *gibbosus, Stizostedion canadense, Perca flavescens, Etheostoma zonale, Roccus chrysops*, and *Morone interrupta*. With few and slight exceptions, all the species of this varied list, representing eight families and twelve genera, are so definitely limited to the northern half of this state that one gets the impression, as he examines these maps in succession, that some invisible barrier to their southward dispersal exists in the neighborhood of the Sangamon River.

### PECULIARITIES OF DISTRIBUTION IN THE LOWER ILLINOISAN GLACIATION

That the distribution of these more northerly species is not limited by the watersheds is shown by the fact that they range across the state indifferently into all the stream systems of northern Illinois. It is not until we compare with our distribution maps a map of the surface geology of the state (Map III.) that we find a plausible explanation of a part, at least, of this peculiar distribution, for all but one of the species above mentioned are wholly excluded from the area of this glaciation, and this excepted species (*Hybopsis dissimilis*) appears in but one locality within the lower glaciation, and that a short distance within its border, on the upper Kaskaskia.

Especially significant in this relation are several cases in which species of this list range southward in the eastern part of the state upon the upper tributaries of the Kaskaskia and the Embarras, for in so doing they simply follow southward the course of the Shelbyville moraine which forms the boundary between the Wisconsin and the lower Illinoisan glaciations in east-central Illinois. The maps for *Noturus flavus, Hybopsis dissimilis, H. kentuckiensis*, and *Stizostedion canadense* are examples.

That this coincidence of distribution and surface geology points to a true explanation is further shown by the maps for twenty-two other species which range more definitely to the southward than the foregoing twelve, but which nevertheless avoid the southern glaciation more or less completely and to an unmistakable degree. For example, 19 of our 94 collection localities for the hogsucker (*Catostomus nigricans*) lie below the Springfield parallel, but only three of them are in the lower Illinoisan glaciation, and these are barely within its borders. Of our thirty localities for the short-headed redhorse (*Moxostoma breviceps*) only two are in this glaciation, and these are near its boundaries on the Embarras and the Kaskaskia. The very abundant minnow *Campostoma anomalum* was taken by us from one hundred and sixty localities, thirty-one of which are south of the Sangamon and eight of them from the non-glaciated area of the Cairo district, but only one of the entire number is within the lower glaciation, and that is on the upper Kaskaskia, just across the limiting moraine. The map for *Notropis cornutus* shows one hundred and sixty-one localities from which collections of this species were made, ninety of them below the Sangamon and twenty-nine in the Cairo district, but only three are in the southern glaciation. Other species testifying to the same effect will be found in the following list of fishes absent from this characteristic southern Illinois district.

Illinois Fishes Rare or wanting in the Lower Illinoisan Glaciation

Short-nosed gar
Common bullhead
Stonecat
Lake carp
Quillback carp
Common sucker
Hogsucker
Short-headed red-horse
Stone-roller
Red-bellied dace
*Notropis cayuga*
*N. heterodon*
Straw-colored minnow
*Notropis gilberti*
Spot-tailed minnow
Common shiner
*Notropis jejunus*
*N. rubrifrons*
Spotted shiner
Storer's chub
River chub
Pike
Menona top-minnow
Trout-perch
Pumpkinseed
Small-mouthed black bass
Sauger
Yellow perch
Banded darter
Rainbow darter
Fan-tailed darter
White bass
Yellow bass
Miller's thumb

Fishes Tolerant of the Lower Illinoisan Glaciation

Dogfish
Channel-cat
Yellow bullhead
Black bullhead
Mud-cat
Tadpole cat
Brindled stonecat
Chub-sucker
Striped sucker
Silvery minnow
Blunt-nosed minnow
*Opsopœodus emiliæ*
Golden shiner
Bullhead minnow
Silverfin
Shiner
Blackfin
*Ericymba buccata*
Silver chub
Grass pike
Common top-minnow
Viviparous top-minnow
Pirate-perch
White crappie
Round sunfish
Warmouth
Green sunfish
Long-eared sunfish
Orange-spotted sunfish
Large-mouthed black bass
Black-sided darter
*Boleosoma camurum*
Sand darter
*Etheostoma jessiæ*
*Boleichthys fusiformis*

Among the ninety-eight Illinois species for which distribution maps have been prepared, thirty-four belong clearly to this group of fishes which seem to avoid the conditions common to the flat gray lands of the southern part of the state. Thirty-five species, on the other hand, are distributed over this glaciation in a way to indicate a tolerance of its conditions if not an indifference to them, the data concerning the remaining twenty-nine species being ambiguous or indecisive in this respect.

Two facts concerning the soil and waters of the lower Illinoisan glaciation may be held to account, at least in part, for the failure of certain species of fishes to thrive in its streams. Compared with the other regions of the state, this oldest of our glaciation areas has developed its drainage system to a point such that the rainfall runs off rapidly in a large number of small streams, leaving no marshes or ponds to hold back the waters during periods of dry weather. It is a level country whose streams fill up quickly and run down rapidly, the smaller ones drying up completely during the midsummer drought, which is here more marked than farther north. These variable and temporary creeks are, of course, less favorable to the maintenance of a varied and permanent fish population than the waters of the earlier Illinoisan or the Wisconsin areas.

As a further consequence of its geological antiquity, involving degenerative chemical changes and a long-continued leaching, the soil of this lower glaciation has become an extremely fine-grained, light-colored clay which, when compact, sheds water almost completely, but which washes into the streams as a fine detritus that remains persistently in suspension and renders the waters very turbid for a long time after a rain. Standing pools, indeed, never become even approximately clear. So persistent is this turbidity, due to very finely divided matter in suspension, that the chemists of the Water Survey find it almost impossible to free the water wholly from suspended solids even by repeated filtration. Furthermore, this soil has a definitely acid reaction, to which is due a notable physical difference between the soils of this area and those of the later glaciations west and north of it. A surplus of lime in a soil coagulates or granulates it, causing its ultimate particles to cohere in larger granules, while in an acid soil this effect is entirely wanting. This lack of granulation in a very finely divided soil increases, of course, the permanent muddiness of its waters as compared with those of the other areas in which lime in the soil renders it alkaline.

The acidity of this southern soil seems not to be of a kind or amount to affect the surface waters sensibly and directly, since the water samples from this region analyzed by the State Water Survey show a soft water, slightly alkaline, and chemically unobjectionable as a medium for fishes.

## CLASSIFICATION AND USE OF ECOLOGICAL DATA

That these conditions are a part, at least, of the cause of the phenomenal distribution of southern Illinios fishes may be shown by a comparison of our ecological data for the fishes of the two lists—one composed of those adapted to the conditions of the lower Illinoisan glaciation and the other of those avoiding them. In the organization of the data of our collections of Illinois fishes, those concerning the character of the water body in which collections were made were classified in a way to show the number of collections of each species taken from each class of situation. By reducing these numbers to ratios of frequency of occurrence, we have a means of exhibiting the preference of species with respect to the situations in which each occurs. *Pimephales notatus*, for example, was found twenty times over a muddy bottom to thirty-four over a bottom of mud and sand, and to forty-six over a bottom of rock and sand. *Aphredoderus sayanus*, on the other hand, was found sixty-two times on a muddy bottom to nineteen times in each of the other situations.

By tabulating data of this description separately for each of the two lists of species referred to—thirty-four species in the one list and thirty-five in the other—and averaging the ratios for each group separately, significant evidence was obtained of the factors which affect the distribution of these fishes.

The species which distribute themselves freely over southern Illinois are those which are generally tolerant of turbid waters, as shown by the fact that 32 per cent. of all our collections of this group came from muddy streams and ponds, 34 per cent. from situations where the bottom was composed largely of rock and sand, and 24 per cent. from a bottom of sand and mud. The species avoiding the central area of southern Illinois, on the other hand, are, as a rule, intolerant of muddy waters, only 10 per cent. of all our data-bearing collections of this group coming from such situations, while 61 per cent. of them were from bottoms of rock and sand, and 29 per cent. from those of sand and mud. It is consequently clear that the suspended detritus of the streams of southern Illinois and the clay and mud of which their banks and bottoms are commonly composed, are an important part, at least, of the cause of the smaller variety of fishes in these waters; and these conditions trace back through the character of the soil to the geological history of the central part of southern Illinois.

### FISHES OF THE OHIO AND OF THE MISSISSIPPI DRAINAGE

A comparison and classification of our distribution maps from another point of view enables us further to distinguish two rather definite groups of species coincident in great measure, but not wholly so, with the two groups which we have found in an opposite relation to the lower Illinoisan glaciation. No less than 27 of our species have either an exclusive or at least a strongly preponderant distribution in the Mississippi drainage in the western and northern parts of the state, while 8 species, on the other hand, are very definitely preponderant in the Ohio drainage in the southern and eastern parts. Nineteen of the 27 species of the first list are also on the list of species excluded from the region of the lower Illinoisan glaciation, while 6 of the 8 species of the second list are also on that of species distributed freely through this southern Illinois district. We have evidence here of another influence strongly affecting distribution, coincident in part with that already discussed, but independent of it also in part, the two causes, or sets of causes, operating together to determine the actual range of most of the species of limited distribution in this state.

The impression produced by an examination of the two sets of maps for the fishes above mentioned, is that of a small group of species, on the one hand, which enter the state from the south and east by way of the Wabash and the smaller tributaries of the Ohio, and, on the other hand, of a much larger group, most of which have entered the state from the west and north, making their way to its interior mainly by the Illinois and the Rock, but sometimes by the Kaskaskia and the Big Muddy also. Species of the Ohio group sometimes seem to spread into the headwaters of adjacent streams, especially into the branches of the Kaskaskia where these come nearest to the Embarras, and into those of the Big Vermilion of the Illinois which are nearest to the Little Vermilion of the Wabash. Some species, however, remain carefully within the tributaries of the Wabash system.

It seems possible that this appearance of an approach to the state and entrance upon its territory from opposite directions is not altogether deceptive, and that the annual movements of the fishes of the state, up the streams at the time of the spring floods, downwards with the recession of the waters, and still farther downwards, for many species, into deeper water in the winter, may take these two contingents of our fish population in opposite directions, from and towards local centers of population for the species, situated on opposite sides of the state. Whether and where such local centers of population actually exist, is a question which can not be answered definitely for lack of numerical or statistical data in the faunal lists and other literature of geographical distribution for the surrounding states. If they exist, the Wabash fishes would constitute one such system, and those of the Mississippi and its tributaries, another.

If we may speculate still further upon this subject, we may perhaps surmise that a general critical analysis of the fish population of the larger area of which Illinois forms the central part, would enable us to distinguish fairly well-defined districts, each with its characteristic assemblage of prevalent species, so associated and ecologically related as to form a balanced assemblage of species, all so adjusted to each other and so advantageously placed in their environment as to constitute a closed system, which the characteristic species of adjacent areas can not enter, or in which they can not permanently remain.

Distribution chiefly in the Ohio Drainage

| | |
|---|---|
| Brindled stonecat | Pirate-perch |
| Green-sided darter | *Notropis illecebrosus* |
| *Boleichthys fusiformis* | *Ericymba buccata* |
| Chub-sucker | Long-eared sunfish |

Distribution chiefly in the Mississippi Drainage

| | |
|---|---|
| Short-nosed gar | White bass |
| Stonecat | Yellow bass |
| Lake carp | Common bullhead |
| *Notropis cayuga* | Short-headed red-horse |

Spot-tailed minnow
*Notropis rubrifrons*
Spotted shiner
Pike
Menona top-minnow
Trout-perch
Pumpkinseed
Sauger
Yellow perch
Banded darter
Red-bellied dace
*Notropis gilberti*
Long-nosed gar
Dogfish
Mongrel buffalo
Black-head minnow
*Hybognathus nubila*
Redfin
Rock bass

### BOUNDARY BETWEEN NORTHERN AND SOUTHERN SPECIES

Recurring next to the distinction made on another page between northern and southern fishes whose areas extend into Illinois but not beyond, and comparing the distribution of these groups within the state, as given on Map CIII., we see that northern and southern species meet and mingle in the western part of the state from Meredosia to Pekin on the Illinois, and from Quincy to Dallas City on the Mississippi, but that in eastern Illinois they are separated by a wide interval extending from Cook county to the mouth of the Embarras, in which interval we have never taken any representative of either group.

The distinctively southern species, although most abundant south of the line 28° 30″, nevertheless go up the Wabash to the Embarras, up the Kaskaskia to Shelby county, up the Mississippi to Henderson county, and up the Illinois to Pekin, also following the branches of the Sangamon to Logan county. The northern species, on the other hand, although most abundant above 40° 20″, come down the Illinois to Meredosia, and down the Mississippi to Quincy.

The boundary between the northern and southern species thus appears as a broad belt some fifty miles in width, extending two thirds of the way across the state just above its center, but widening to a distance of one hundred and seventy-five miles on the eastern boundary.

### GENERAL FEATURES OF ECOLOGICAL DISTRIBUTION

In addition to the general distribution of Illinois fishes over the North American continent, their general or partial distribution within the state, and the unevenness of their distribution over the different divisions of the state, hydrographic, climatic, and geological, there are also recognizable differences and inequalities of distribution corresponding to the size of the water bodies in which the species are found, to the nature of the bottom and the consequent clearness and purity of the waters, and to the existence and rate of current or flow in the waters inhabited by them. In this class of divisions, geological distribution merges into ecological relation, the distribution of species being no longer by geological areas, but by ecological situations. In this sense two species may occupy precisely the same territory without ever coming into any effective contact with each other, because they are differently related to certain features of their environment.

As an explanation of the more general facts of distribution requires an analysis and interpretation of continental, terrestrial, and even cosmic agencies affecting it, so an understanding of what we may call the ecological distribution of a species requires a corresponding analysis of the ecological features of the region. Such an analysis can here be carried but a little way, since the ecological data borne by our collections are only of a very general type; but such as they are, they may, if used with discretion, add definiteness and detail and some degree of statistical precision to our knowledge of this part of the subject.

My statistics of associate occurrence exhibit in the most interesting manner the frequent tendency of closely allied species inhabiting the same territory to avoid each other's company and thus to evade competition with one another by the choice of different haunts and situations within the area of their common habitation. In consequence of this tendency, we sometimes find widely unlike species more closely and commonly associated in our collections than like, the ecological repulsion of each for its similars bringing dissimilars together into more or less definite associate groups. The sunfishes proper, for example—that is, the *Centrarchidæ* exclusive of the black bass—although a homogeneous group of species as to form and external structure, are a diverse assemblage as to ecological relationships. If we compare the proportionate frequency with which the closely similar species of the genus *Lepomis* have been taken together in our collections—in the same haul of the net, or from the same situation at the same time—with the frequency of associate occurrence of the widely dissimilar species of the other genera of the family, we find that the unlike species have been taken together much more frequently than the like—in a ratio of 1½ to 1,—that the species of *Lepomis* have, indeed, been taken in company with species of other genera considerably more frequently than with each other. The sunfishes, consequently, are not an associate group, but tend to disperse themselves over a large variety of ecological situations, those least like each other being most likely to meet on common ground where their unlike capacities enable them to live together in a non-competitive way. Other striking examples of this reaction might be pointed out in the suckers, the minnows, the catfishes (especially the bullheads), and the top-minnows.

Ninety-seven of our species have been collected in large enough numbers, and from a sufficient variety of locations, to give us data for comparison with reference to the general character and size of the water bodies which they prefer; 62 species furnish available data concerning the bottom or substratum of these water bodies; and 49 species, data concerning current and rate of flow. The numbers of collections for the various species covered by these figures vary greatly from a minimum of 10 collections of a species to a maximum of 376. Unfortunately, the larger and more important fishes are commonly represented by the smaller numbers of collections, and statements made concerning these are less likely to be found fairly accurate and generally correct than are those concerning the smaller fishes, represented by larger numbers of collections.

One available set of our data may best be presented in tabular form, for such use as the student may wish to make of them; and to this table we add, as an illustration of its use, only a few statements concerning the more conspicuous ecological groups of our Illinois fishes.

By assorting the species according to the size of the ratios of frequency of occurrence for each class of situations distinguished in this table, we may separate those strongly preferring the given situation from those apparently avoiding it. In this way we learn that the species occurring in our collections with disproportionate frequency in the larger rivers of the state are the mud-cat (*Leptops olivaris*), one of the river carp (*carpio*), the toothed herring (*Hiodon tergisus*), and the sheepshead (*Aplodinotus*), among the larger fishes; and a small darter (*Cottogaster shumardi*), the trout-perch (*Percopsis guttatus*), and a minnow (*Hybopsis dissimilis*) among the smaller fishes.

The principal larger fishes of the smaller rivers make a much longer list, comprising the hogsucker, two of the native carp (*velifer* and *difformis*), a species of red-horse (*aureolum*), the rock bass, and the small-mouthed black bass; and the principal smaller species are six darters (*Etheostoma zonale*, *Hadropterus phoxocephalus*, *H. aspro*, *Diplesion blennioides*, *Etheostoma cœruleum*, and *Ammocrypta pellucida*), a stonecat (*Noturus flavus*), and *Hybopsis kentuckiensis*, and four other minnows, all of the genus *Notropis* (*rubrifrons*, *gilberti*, *blennius*, and *cornutus*)—their ratios running from 70 per cent. for *rubrifrons* to 41 per cent. for *cornutus*.

The species of our list which have from 50 to 100 per cent. of their representatives in creeks, as illustrated by our collections, include three sunfishes (the green sunfish, the round sunfish, and the long-eared sunfish), three suckers (the common sucker, the chub-sucker, and the striped sucker), four darters, ten minnows, and the brindled stonecat.

The larger species found most abundantly in lakes, ponds, and other stagnant waters were the common bullhead, the buffaloes, the yellow perch, the white bass, the yellow bass, the large-mouthed black bass, and five sunfishes (both crappies, the warmouth, the pumpkinseed, and the bluegill); and the smaller kinds were the smallest of our fishes (*Microperca punctulata*), another darter (*Boleichthys fusiformis*), two minnows (*Notropis cayuga* and *N. heterodon*), the mud-minnow, and a killifish (*Fundulus dispar*).

Turning next to the 62 species for which our data of preference or avoidance of a muddy bottom are available, we find 7 species whose ratios of frequency of occurrence in such situations range from 43 to 88 per cent., and which may consequently be called limophagous fishes. These are the warmouth sunfish, the black and the yellow bullheads, the pirate-perch, a single darter (*Boleosoma camurum*), and two minnows, the golden shiner and the common shiner (*Notropis cornutus.*)

It is interesting to find, by an examination of our maps, that all these 7 species are freely distributed over the lower Illinoisan glaciation of the southern part of the state, where, as we have already shown, only fishes indifferent to a peculiarly persistent turbidity of the water are likely to occur.

By selecting from this same list of 62 species those with the lowest ratios of frequency over a muddy bottom, we get 13 species (with ratios of 4 to 10 per cent.) which evidently avoid such situations; and these, again, are without exception so distributed that the area of the lower Illinoisan glaciation is almost never entered by them. These are one of the native carp (*velifer*), a species of red-horse (*aureolum*), the small-mouthed black bass, two darters (*Hadropterus phoxocephalus* and *Etheostoma cœruleum*), five minnows (*Campostoma anomalum*, *Notropis heterodon*, *Ericymba buccata*, *Hybopsis kentuckiensis*, and *Notropis blennius*), two stonecats, and the little brook silverside (*Labidesthes*).

A more precise statement and a fuller discussion of the ecological relations of our fishes, including statistics of companionship for the various species, as shown by the frequency of their joint occurrence in collections, must be left for later contributions.

Attention may be profitably called, in conclusion, to the economic significance of the details of distribution of the various species as influenced both by geographical and ecological conditions, since a proper understanding and application of these facts will prevent wasteful efforts to introduce species where they do not belong and can not thrive. Indeed, the more detailed our knowledge of favorable, and even optimum, conditions for the different species, and the more exact, also, our acquaintance with the relations of each species of fish to its companion species in any associate assemblage, the more intelligent, and hence the more successful, in the long run, will be our efforts to extend the range and multiply the numbers of the more useful species and to lessen the numbers of those especially injurious.

## ECOLOGICAL TABLE

### ALL ILLINOIS SPECIES WITH AT LEAST TEN AVAILABLE RECORDS EACH*

| Jordan and Evermann Nos. | Species | Water (97 species) | | | | | Current (49 species) | | | | Bottom (62 species) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Available collections | Larger rivers | Smaller rivers | Creeks | Lakes, ponds, etc. | Available collections | Swift to moderate | Sluggish to stagnant | Variable | Available collections | Mud | Rock and sand | Mud and sand |
| 151 | Long-nosed gar | 35 | 25 | 19 | 7 | 22 | .... | .... | .... | .... | .... | .... | .... | .... |
| 152 | Short-nosed gar | 57 | 28 | 24 | 4 | 25 | .... | .... | .... | .... | .... | .... | .... | .... |
| 155 | Dogfish | 37 | 18 | 7 | 6 | 30 | .... | .... | .... | .... | .... | .... | .... | .... |
| 207 | Channel-cat | 171 | 20 | 32 | 27 | 8 | 31 | 68 | 19 | 13 | 75 | 21 | 44 | 35 |
| 215 | Yellow bullhead | 122 | 7 | 6 | 37 | 23 | 14 | 36 | 43 | 21 | 35 | 43 | 34 | 23 |
| 217 | Common bullhead | 48 | 15 | 5 | 4 | 44 | .... | .... | .... | .... | .... | .... | .... | .... |
| 218 | Black bullhead | 244 | 8 | 21 | 37 | 26 | 38 | 37 | 53 | 10 | 56 | 54 | 46 | .... |
| 221 | Mud-cat | 30 | 53 | 21 | 5 | 8 | .... | .... | .... | .... | .... | .... | .... | .... |
| 222 | Stonecat | 41 | 10 | 53 | 34 | .... | 15 | 60 | 13 | 26 | 24 | 8 | 58 | 34 |
| 223 | Tadpole cat | 193 | 17 | 5 | 23 | 41 | 21 | 48 | 43 | 9 | 45 | 29 | 27 | 44 |
| 231 | Brindled stonecat | 30 | 3 | 36 | 60 | .... | .... | .... | .... | .... | 13 | 8 | 62 | 30 |
| 261 | Red-mouth buffalo | 39 | 13 | .... | 9 | 48 | .... | .... | .... | .... | .... | .... | .... | .... |
| 262 | Mongrel buffalo | 19 | 17 | .... | 7 | 45 | .... | .... | .... | .... | .... | .... | .... | .... |
| 264 | Small-mouth buffalo | 52 | 14 | 12 | 4 | 49 | .... | .... | .... | .... | .... | .... | .... | .... |
| 265 | River carp | 15 | 47 | .... | 8 | 10 | .... | .... | .... | .... | .... | .... | .... | .... |
| 266 | Blunt-nosed carp | 102 | 9 | 42 | 30 | 12 | 16 | 50 | 25 | 25 | 47 | 21 | 36 | 43 |
| 268 | Quillback carp | 70 | 10 | 50 | 19 | 5 | 19 | 47 | 32 | 21 | 28 | 4 | 60 | 36 |

*The figures of this table, except those in the columns for available collections, are ratios of frequency of the species in our collections, computed with due reference to the comparative numbers of collections of all kinds made in each situation.

ECOLOGICAL TABLE—*continued*

ALL ILLINOIS SPECIES WITH AT LEAST TEN AVAILABLE RECORDS EACH

| Jordan and Evermann Nos. | Species | Water (97 species) | | | | | Current (49 species) | | | | Bottom (62 species) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Available collections | Larger rivers | Smaller rivers | Creeks | Lakes, ponds, etc. | Available collections | Swift to moderate | Sluggish to stagnant | Variable | Available collections | Mud | Rock and sand | Mud and sand |
| 289 | Common sucker...... | 132 | 3 | 19 | 71 | 1 | 49 | 39 | 47 | 14 | 79 | 13 | 44 | 43 |
| 294 | Hogsucker........... | 99 | 4 | 63 | 25 | 4 | 71 | 20 | 63 | 17 | 59 | .... | 54 | 46 |
| 302a | Chub-sucker.......... | 131 | 9 | 12 | 57 | 14 | 23 | 52 | 48 | .... | 57 | 32 | 39 | 29 |
| 303 | Striped sucker........ | 46 | 2 | 31 | 53 | 3 | .... | .... | .... | .... | 19 | 26 | 32 | 42 |
| 305 | White-nosed sucker... | 18 | 7 | 44 | 20 | 6 | .... | .... | .... | .... | .... | .... | .... | .... |
| 314 | Common red-horse.... | 143 | 9 | 32 | 40 | 4 | 47 | 57 | 28 | 15 | 65 | 6 | 55 | 39 |
| 319 | Short-headed red-horse | 55 | 13 | 25 | 15 | 22 | .... | .... | .... | .... | 14 | 14 | 43 | 43 |
| 328 | Stone-roller.......... | 195 | 3 | 37 | 55 | 1 | 65 | 63 | 23 | 14 | 105 | 7 | 57 | 36 |
| 334 | Red-bellied dace...... | 23 | 10 | .... | 71 | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| 340 | Silvery minnow....... | 183 | 12 | 36 | 32 | 7 | 30 | 47 | 40 | 13 | 67 | 33 | 40 | 27 |
| 349 | Black-head minnow... | 95 | 14 | 30 | 48 | 4 | 12 | 50 | 42 | 8 | 44 | 25 | 41 | 34 |
| 350 | Blunt-nosed minnow.. | 376 | 5 | 34 | 43 | 12 | 108 | 50 | 34 | 16 | 202 | 20 | 46 | 34 |
| 355 | Horned dace......... | 151 | 4 | 28 | 63 | 2 | 42 | 48 | 36 | 16 | 81 | 17 | 47 | 36 |
| 391 | *Opsopœodus emiliæ*.... | 40 | 13 | 6 | 36 | 32 | .... | .... | .... | .... | .... | .... | .... | .... |
| 394 | Golden shiner........ | 303 | 12 | 17 | 29 | 32 | 28 | 32 | 57 | 11 | 82 | 44 | 29 | 27 |
| 398 | Bullhead minnow..... | 187 | 17 | 31 | 28 | 7 | 36 | 67 | 17 | 16 | 62 | 11 | 44 | 45 |
| 405 | *Notropis cayuga*...... | 29 | .... | 13 | 26 | 57 | 13 | 54 | 38 | 8 | 15 | .... | 27 | 73 |
| 406 | *N. heterodon*.......... | 92 | 19 | 1 | 19 | 60 | .... | .... | .... | .... | 14 | 7 | 22 | 71 |
| 408 | Straw-colored minnow | 185 | 7 | 44 | 37 | 3 | 63 | 49 | 26 | 25 | 103 | 10 | 50 | 40 |

ECOLOGICAL TABLE—*continued*

ALL ILLINOIS SPECIES WITH AT LEAST TEN AVAILABLE RECORDS EACH

| Jordan and Evermann Nos. | Species | Water (97 species) | | | | | Current (49 species) | | | | Bottom (62 species) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Available collections | Larger rivers | Smaller rivers | Creeks | Lakes, ponds, etc. | Available collections | Swift to moderate | Sluggish to stagnant | Variable | Available collections | Mud | Rock and sand | Mud and sand |
| 420 | *Notropis gilberti* | 30 | 2 | 49 | 43 | 2 | .... | .... | .... | .... | 18 | 11 | 45 | 44 |
| 426 | *N. illecebrosus* | 11 | .... | .... | 100 | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| 428 | Spot-tailed minnow | 147 | 28 | 5 | 2 | 39 | .... | .... | .... | .... | 10 | 20 | 80 | .... |
| 432 | Redfin | 163 | 24 | 32 | 20 | 14 | 13 | 46 | 38 | 16 | 55 | 27 | 40 | 33 |
| 448 | Silverfin | 268 | 6 | 39 | 40 | 4 | 65 | 54 | 26 | 20 | 126 | 13 | 56 | 31 |
| 456 | Common shiner | 178 | 2 | 41 | 50 | 4 | 76 | 45 | 36 | 19 | 102 | 44 | 48 | 8 |
| 476 | *Notropis jejunus* | 51 | 27 | 19 | 13 | 11 | .... | .... | .... | .... | 12 | 25 | 67 | 8 |
| 485 | Shiner | 206 | 20 | 36 | 15 | 11 | 23 | 57 | 30 | 13 | 48 | 21 | 64 | 14 |
| 489 | *Notropis rubrifrons* | 13 | 4 | 70 | 26 | .... | 11 | 45 | 18 | 36 | 11 | .... | 82 | 18 |
| 498a | Blackfin | 208 | 3 | 32 | 65 | .... | 69 | 41 | 45 | 14 | 109 | 17 | 43 | 40 |
| 499 | *Ericymba buccata* | 74 | 1 | 18 | 81 | .... | 14 | 43 | 29 | 28 | 38 | 8 | 63 | 29 |
| 501 | Sucker-mouthed minnow | 159 | 5 | 36 | 53 | 1 | 53 | 53 | 24 | 23 | 92 | 15 | 51 | 34 |
| 528 | Spotted shiner | 11 | 50 | 27 | 22 | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| 533 | Silver chub | 41 | 5 | 29 | 66 | .... | 13 | 77 | 15 | 7 | 20 | 30 | 55 | 15 |
| 534 | Storer's chub | 28 | 21 | 32 | 11 | 10 | .... | .... | .... | .... | .... | .... | .... | .... |
| 536 | River chub | 129 | 4 | 41 | 51 | 1 | 55 | 53 | 24 | 23 | 74 | 8 | 43 | 49 |
| 674 | Toothed herring | 10 | 46 | .... | .... | 16 | .... | .... | .... | .... | .... | .... | .... | .... |
| 677 | Gizzard-shad | 105 | 17 | 32 | 7 | 20 | .... | .... | .... | .... | 22 | 23 | 55 | 22 |
| 919 | Mud-minnow | 34 | 7 | 24 | 8 | 49 | .... | .... | .... | .... | .... | .... | .... | .... |

ECOLOGICAL TABLE—*continued*

ALL ILLINOIS SPECIES WITH AT LEAST TEN AVAILABLE RECORDS EACH

| Jordan and Evermann Nos. | Species | Water (97 species) | | | | | Current (49 species) | | | | Bottom (62 species) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Available collections | Larger rivers | Smaller rivers | Creeks | Lakes, ponds, etc. | Available collections | Swift to moderate | Sluggish to stagnant | Variable | Available collections | Mud | Rock and sand | Mud and sand |
| 922 | Grass pike | 111 | 7 | 16 | 34 | 30 | 14 | 36 | 57 | 7 | 29 | 38 | 21 | 41 |
| 939 | Menona top-minnow | 17 | .... | .... | 42 | 49 | .... | .... | .... | .... | .... | .... | .... | .... |
| 966 | Striped top-minnow | 83 | 11 | .... | 3 | 72 | .... | .... | .... | .... | .... | .... | .... | .... |
| 967 | Common top-minnow | 208 | 6 | 25 | 49 | 12 | 34 | 41 | 50 | 9 | 81 | 32 | 42 | 26 |
| 1000 | Viviparous top-minnow | 17 | 12 | 21 | 32 | 12 | .... | .... | .... | .... | .... | .... | .... | .... |
| 1145 | Trout-perch | 15 | 52 | .... | 4 | 19 | .... | .... | .... | .... | .... | .... | .... | .... |
| 1147 | Pirate-perch | 100 | 18 | 5 | 42 | 21 | 14 | 21 | 72 | 7 | 37 | 62 | 19 | 19 |
| 1177 | Brook silverside | 120 | 13 | 28 | 13 | 36 | 16 | 31 | 44 | 25 | 21 | 10 | 62 | 28 |
| 1381 | White crappie | 166 | 15 | 19 | 17 | 34 | 14 | 64 | 29 | 7 | 43 | 35 | 49 | 16 |
| 1382 | Black crappie | 179 | 17 | 16 | 10 | 42 | .... | .... | .... | .... | 28 | 25 | 50 | 25 |
| 1383 | Round sunfish | 11 | .... | .... | 69 | 30 | .... | .... | .... | .... | .... | .... | .... | .... |
| 1385 | Rock bass | 48 | 7 | 49 | 24 | 13 | 20 | 55 | 15 | 30 | 27 | .... | 48 | 52 |
| 1387 | Warmouth | 122 | 12 | 17 | 12 | 45 | .... | .... | .... | .... | 17 | 88 | 12 | .... |
| 1391 | Green sunfish | 313 | 7 | 25 | 52 | 11 | 80 | 39 | 45 | 16 | 156 | 28 | 41 | 31 |
| 1397 | *Lepomis miniatus* | 23 | 10 | .... | 11 | 41 | .... | .... | .... | .... | .... | .... | .... | .... |
| 1399 | Long-eared sunfish | 112 | 2 | 12 | 76 | 4 | 17 | 41 | 47 | 12 | 41 | 37 | 63 | .... |
| 1400 | Orange-spotted sunfish | 174 | 12 | 25 | 34 | 20 | 21 | 38 | 38 | 24 | 60 | 30 | 35 | 35 |
| 1403 | Bluegill | 214 | 16 | 10 | 7 | 54 | .... | .... | .... | .... | 24 | 25 | 58 | 17 |
| 1408 | Pumpkinseed | 85 | 6 | 17 | 4 | 56 | .... | .... | .... | .... | .... | .... | .... | .... |

ECOLOGICAL TABLE—*continued*

ALL ILLINOIS SPECIES WITH AT LEAST TEN AVAILABLE RECORDS EACH

| Jordan and Evermann Nos. | Species | Water (97 species) | | | | | Current (49 species) | | | | Bottom (62 species) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Available collections | Larger rivers | Smaller rivers | Creeks | Lakes, ponds, etc. | Available collections | Swift to moderate | Sluggish to stagnant | Variable | Available collections | Mud | Rock and sand | Mud and sand |
| 1409 | Small-mouthed black bass | 100 | 6 | 43 | 23 | 19 | 40 | 55 | 18 | 27 | 50 | 6 | 68 | 26 |
| 1410 | Large-mouthed black bass | 211 | 8 | 20 | 17 | 40 | 19 | 58 | 26 | 16 | 48 | 19 | 54 | 27 |
| 1413 | Pike-perch | 36 | 16 | 10 | 8 | 33 | .... | .... | .... | .... | .... | .... | .... | .... |
| 1414 | Sauger | 16 | 36 | .... | 4 | 25 | .... | .... | .... | .... | .... | .... | .... | .... |
| 1415 | Yellow perch | 83 | 20 | 7 | 3 | 51 | .... | .... | .... | .... | .... | .... | .... | .... |
| 1417 | Log-perch | 60 | 10 | 38 | 27 | 19 | 14 | 93 | 7 | .... | 20 | .... | 100 | .... |
| 1418 | *Hadropterus phoxocephalus* | 85 | 7 | 57 | 27 | 3 | 32 | 87 | 13 | .... | 48 | 6 | 94 | .... |
| 1421 | Black-sided darter | 159 | 6 | 42 | 47 | 1 | 49 | 70 | 30 | .... | 76 | 16 | 84 | .... |
| 1436 | *Cottogaster shumardi* | 16 | 55 | .... | 4 | 18 | .... | .... | .... | .... | .... | .... | .... | .... |
| 1443 | Green-sided darter | 24 | .... | 46 | 53 | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| 1446 | Johnny darter | 234 | 3 | 25 | 53 | 16 | 71 | 68 | 32 | .... | 126 | 11 | 89 | .... |
| 1448 | *Boleosoma camurum* | 107 | 9 | 23 | 42 | 17 | 17 | 41 | 59 | .... | 39 | 60 | 40 | .... |
| 1450 | Sand darter | 19 | 13 | 47 | 39 | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| 1461 | Banded darter | 32 | 3 | 74 | 23 | .... | 18 | 89 | 11 | .... | 19 | 11 | 89 | .... |
| 1474 | *Etheostoma jessiæ* | 158 | 20 | 19 | 16 | 24 | 12 | 83 | 17 | .... | 31 | 23 | 67 | .... |
| 1477 | Rainbow darter | 80 | 3 | 44 | 45 | 1 | 29 | 83 | 17 | .... | 37 | 8 | 92 | .... |
| 1489 | *Etheostoma squamiceps* | 10 | .... | 35 | 64 | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| 1490 | Fan-tailed darter | 30 | 9 | .... | 87 | 4 | .... | .... | .... | .... | 11 | .... | 100 | .... |

ECOLOGICAL TABLE—*concluded*

ALL ILLINOIS SPECIES WITH AT LEAST TEN AVAILABLE RECORDS EACH

| Jordan and Evermann Nos. | Species | Water (97 species) | | | | | Current (49 species) | | | | Bottom (62 species) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Available collections | Larger rivers | Smaller rivers | Creeks | Lakes, ponds, etc. | Available collections | Swift to moderate | Sluggish to stagnant | Variable | Available collections | Mud | Rock and sand | Mud and sand |
| 1494 | *Bolcichthys fusiformis* | 56 | 1 | 12 | 24 | 62 | .... | .... | .... | .... | 21 | 33 | 67 | .... |
| 1497 | Least darter | 12 | .... | .... | 4 | 95 | .... | .... | .... | .... | .... | .... | .... | .... |
| 1529 | White bass | 56 | 28 | .... | 8 | 46 | .... | .... | .... | .... | .... | .... | .... | .... |
| 1531 | Yellow bass | 100 | 20 | 4 | .... | 52 | .... | .... | .... | .... | .... | .... | .... | .... |
| 1871 | Sheepshead | 57 | 29 | 16 | 1 | 27 | .... | .... | .... | .... | .... | .... | .... | .... |

## GENERAL SUMMARY

The principal conclusions of this article may be thus summarized:

1. The 150 native species of Illinois fishes here recognized, are so distributed within and without the state as to indicate an unequal commingling of the faunæ of the surrounding territories, southeastern species preponderating over southwestern, northeastern over northwestern, eastern over western, and southern over northern.

2. The Illinois basin may be taken as typical, in its fish population, of the ichthyology of the whole state—occupying, as it does, a central position, including more than half the area of the state, and containing a great variety of waters and situations fit for the habitation of fishes, and more than four fifths of the species found anywhere in Illinois. The more important fishes of the state not known from this basin are a few distinctively northern species, most of which are peculiar to the Great Lakes, and a few southern species which do not range as far north, in this state, as the mouth of the Illinois. The

remainder are very rare in our territory, most of them coming from the west and south, and they are extremely insignificant elements of our fish fauna.

3. If the ten stream systems of the state be brought into comparison one with another, it appears that the six larger areas, containing the largest streams and presenting the greatest variety of situations, are much more closely affiliated ichthyologically than are the four smaller areas. The least closely affiliated with each other and with all the rest are the Michigan district of northeastern Illinois and the Big Muddy basin in the southwest. The closest relations are those between the Illinois, the Rock, and the Mississippi.

4. In the absence, in Illinois, of geographical barriers to the dispersal of fishes, the causes influencing their distribution are climatic, geologic, and ecological. As Illinois extends through 5.5° of latitude, differences of climate between the northern and the southern sections of the state are sufficient to affect, in considerable measure, the distribution of its plant and animal species—differences which, in its ichthyology, express themselves in the presence in northern Illinois, but not in southern, of 17 species of general northward range; and in southern Illinois, but not in northern, of 14 species of general southward range. These two groups of species meet and mingle in the great north and south rivers of the western half of the state, in an area of common occupation about fifty miles in width, from the latitude of Springfield northward; while on the eastern boundary of the state, occupied by small streams of various direction, these groups are separated by an interval of about a hundred and seventy-five miles over which no representative of either group has been taken.

5. Geological limitations to the dispersal of fishes are illustrated by peculiarities of distribution in southern Illinois as related to the area of the lower Illinoisan glaciation, which 34 species evidently avoid while 35 other species enter upon it freely and inhabit it successfully. A comparison of the ecological relations of these two groups of species as represented by our collection records, shows that they are strongly distinguished by the repugnance of the first group, and the indifference of the second, to waters with a muddy bottom, collections of the first group having been made from such situations in an average ratio more than three times as great as that for the second. The waters of this region, on the other hand, are re-

markably and persistently turbid, never clearing themselves spontaneously. This is owing in part to the extremely fine division of the soil, and in part to its generally acid character and the consequent lack of "granulation," or cohesion of its ultimate particles in granules, such as occurs in the alkaline soils of the other geological areas of the state. The surface waters of the district are soft and slightly alkaline, but contain much silica, and much solid matter in suspension which it is extremely difficult to remove completely by any ordinary filtering or precipitation process. The inference is plain that it is to this condition of the waters—due to the geological history of the soil of this region—that the unequal distribution of these fishes is largely to be attributed.

6. In consequence of another clearly recognizable inequality of distribution, partly coincident with the two preceding and partly independent of them, two additional groups may be distinguished; one of 8 species, distributed in this state mainly through the Ohio and Wabash drainage, and the other of 27 species, distributed through the Mississippi and its more northerly tributaries. The general distribution throughout the country at large of each of these two groups of species is quite varied, and offers no hint of a reason for these differences in Illinois. Two hypothetical explanations are suggested—the first presupposing different centers of population outside the state, from and towards which these species move, into and out of Illinois streams, with the spring rise, summer recession, and winter cooling of the waters, one of these centers to the west and north, and one to the east and south; and the second presupposing an organization of the fish population into more or less distinct communities of mutually well-adjusted species, each community so adapted to its environment that members of adjacent communities can not successfully intrude upon its territory.

7. An analysis of our statistical data of ecological distribution gives us many instances of a marked difference in preference of situation between nearly related species inhabiting the same area, the effect of which is to break the force of a competition between these species such as would prevail if they were similarly distributed ecologically as well as geographically. Closely related species are, as a consequence, often found much less frequently associated in their common territory than either is with widely unlike species of the same geographical range. Exceptions to this rule are found

where similar species occupy adjacent areas of distribution which merely overlap by their borders.

8. A table of the broader ecological relations of 97 species of Illinois fishes is made the basis of a few general statements, but that subject as a whole is reserved for more detailed treatment elsewhere.

## List of Maps

The general map of the distribution of collections (Map IV.) shows, by the location of the red spots, all the localities from which collections of fishes have been made by us in the work of the Natural History Survey. The distribution maps for the various species indicate in the same way all the localities from which representatives of the species have been taken. *For an accurate idea of the significance of these species maps, each should be compared with Map IV.*

The following numbered list of the counties of the state corresponds to the figures on these maps.

1. Jo Daviess
2. Stephenson
3. Winnebago
4. Boone
5. McHenry
6. Lake
7. Cook
8. Du Page
9. Kane
10. DeKalb
11. Ogle
12. Lee
13. Carroll
14. Whiteside
15. Rock Island
16. Mercer
17. Henry
18. Bureau
19. Putnam
20. La Salle
21. Kendall
22. Grundy
23. Will
24. Kankakee
25. Iroquois
26. Ford
27. Livingston
28. Marshall
29. Woodford
30. Stark
31. Peoria
32. Knox
33. Warren
34. Henderson
35. Hancock
36. McDonough
37. Fulton
38. Mason
39. Tazewell
40. McLean
41. Vermilion
42. Champaign
43. Piatt
44. Dewitt
45. Logan
46. Menard
47. Cass
48. Schuyler
49. Brown
50. Adams
51. Pike
52. Scott
53. Morgan
54. Sangamon
55. Christian
56. Macon
57. Moultrie
58. Douglas
59. Edgar
60. Clark
61. Coles
62. Cumberland
63. Shelby
64. Montgomery
65. Macoupin
66. Greene
67. Calhoun
68. Jersey
69. Madison
70. Bond
71. Fayette
72. Effingham
73. Jasper
74. Crawford
75. Lawrence
76. Richland
77. Clay
78. Marion
79. Clinton
80. St. Clair
81. Monroe
82. Randolph
83. Washington
84. Perry
85. Jefferson
86. Wayne
87. Edwards
88. Wabash
89. White
90. Hamilton
91. Franklin
92. Jackson
93. Williamson
94. Saline
95. Gallatin
96. Hardin
97. Pope
98. Johnson
99. Union
100. Alexander
101. Pulaski
102. Massac

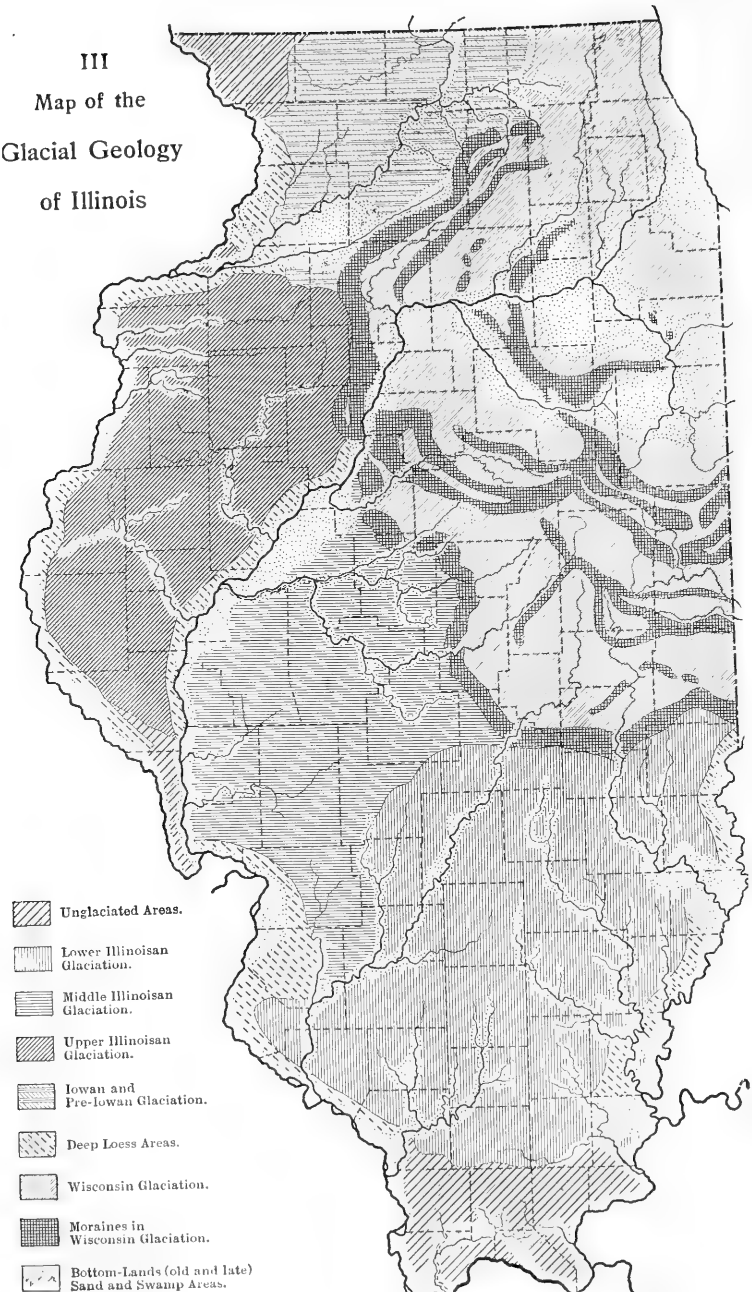
V. Lepisosteus osseus
VI. L. platostomus
VII. Amia calva
VIII. Dorosoma cepedianum
IX. Ictiobus cyprinella
X. I. urus
XI. I. bubalus
XII. Carpiodes carpio
XIII. C. difformis
XIV. C. velifer
XV. C. thompsoni
XVI. Erimyzon sucetta oblongus
XVII. Minytrema melanops
XVIII. Catostomus commersonii
XIX. C. nigricans
XX. Moxostoma anisurum
XXI. M. aureolum
XXII. M. breviceps
XXIII. Campostoma anomalum
XXIV. Chrosomus erythrogaster
XXV. Hybognathus nuchalis
XXVI. H. nubila
XXVII. Pimephales promelas
XXVIII. P. notatus
XXIX. Semotilus atromaculatus
XXX. Opsopœodus emiliæ
XXXI. Abramis crysoleucas
XXXII. Cliola vigilax
XXXIII. Notropis cayuga
XXXIV. N. heterodon
XXXV. N. blennius
XXXVI. N. gilberti
XXXVII. N. illecebrosus
XXXVIII. N. hudsonius
XXXIX. N. lutrensis
XL. N. whipplii
XLI. N. cornutus
XLII. N. jejunus
XLIII. N. atherinoides
XLIV. N. rubrifrons
XLV. N. umbratilis atripes
XLVI. Ericymba buccata
XLVII. Phenacobius mirabilis
XLVIII. Hybopsis dissimilis
XLIX. H. amblops
L. H. storerianus
LI. H. kentuckiensis
LII. Ictalurus punctatus
LIII. Ameiurus natalis
LIV. A. nebulosus
LV. A. melas
LVI. Leptops olivaris
LVII. Noturus flavus
LVIII. Schilbeodes gyrinus
LIX. S. miurus
LX. Umbra limi
LXI. Esox vermiculatus
LXII. E. lucius
LXIII. Fundulus diaphanus menona
LXIV. F. dispar
LXV. F. notatus
LXVI. Gambusia affinis
LXVII. Percopsis guttatus
LXVIII. Labidesthes sicculus
LXIX. Aphredoderus sayanus
LXX. Pomoxis annularis
LXXI. P. sparoides
LXXII. Centrarchus macropterus
LXXIII. Ambloplites rupestris
LXXIV. Chænobryttus gulosus
LXXV. Lepomis miniatus
LXXVI. L. megalotis
LXXVII. L. humilis
LXXVIII. L. pallidus
LXXIX. Eupomotis gibbosus
LXXX. Micropterus dolomieu
LXXXI. M. salmoides
LXXXII. Stizostedion vitreum
LXXXIII. S. canadense griseum
LXXXIV. Perca flavescens
LXXXV. Percina caprodes
LXXXVI. Hadropterus phoxocephalus
LXXXVII. H. aspro
LXXXVIII. Cottogaster shumardi
LXXXIX. Diplesion blennioides
XC. Boleosoma nigrum
XCI. B. camurum
XCII. Ammocrypta pellucida
XCIII. Etheostoma zonale
XCIV. E. jessiæ
XCV. E. cœruleum
XCVI. E. squamiceps
XCVII. E. flabellare
XCVIII. Boleichthys fusiformis
XCIX. Microperca punctulata
C. Roccus chrysops
CI. Morone interrupta
CII. Aplodinotus grunniens

## I & II
## Stream systems and Sections of Illinois

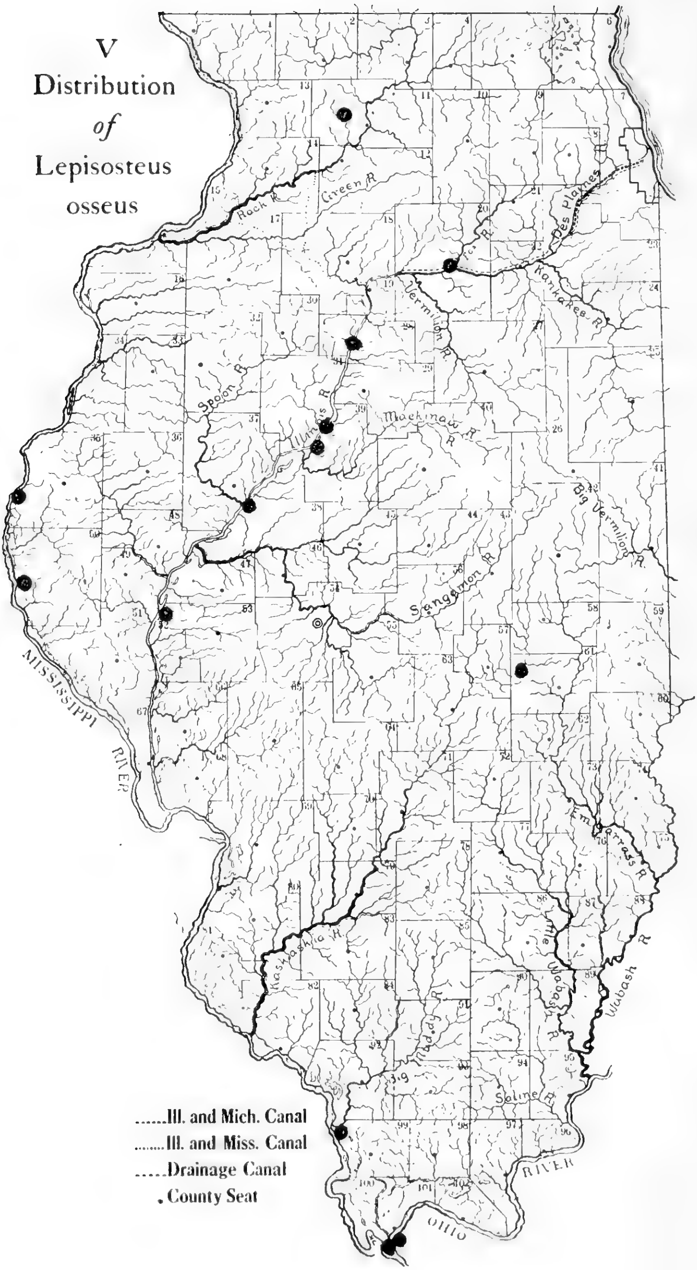

......Ill. and Mich. Canal
........Ill. and Miss. Canal
----Drainage Canal
• County Seat

III

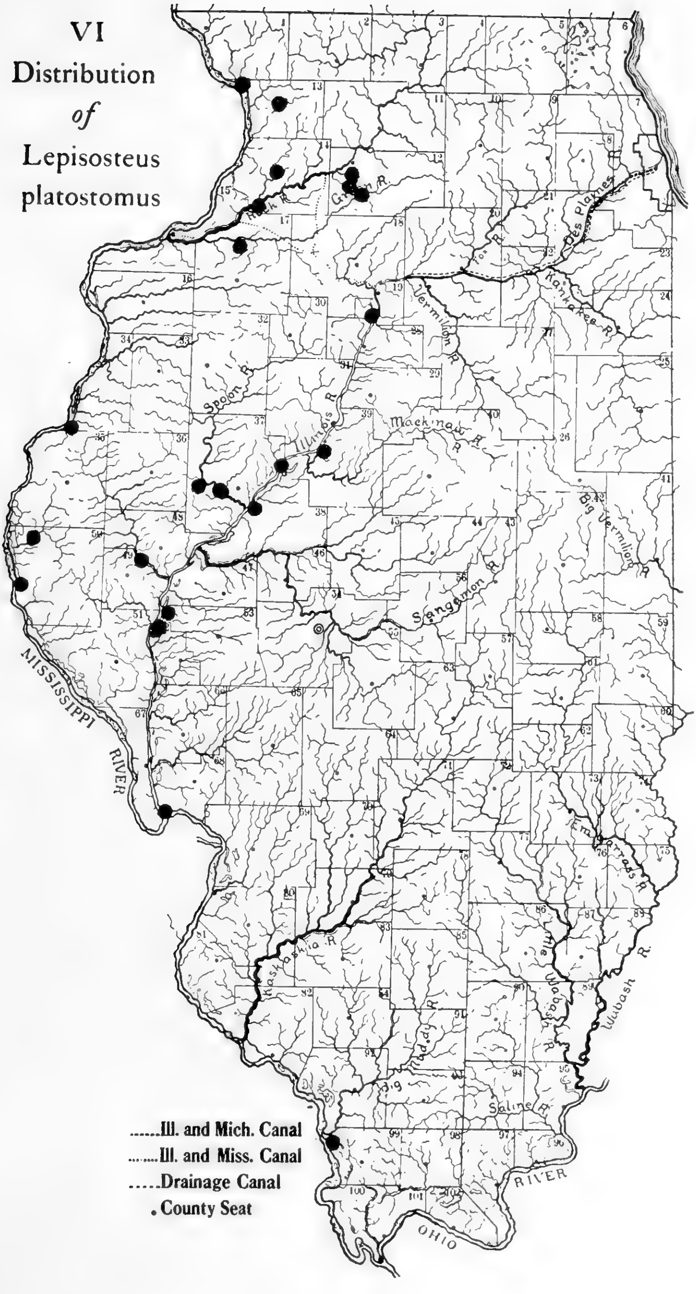
Map of the Glacial Geology of Illinois



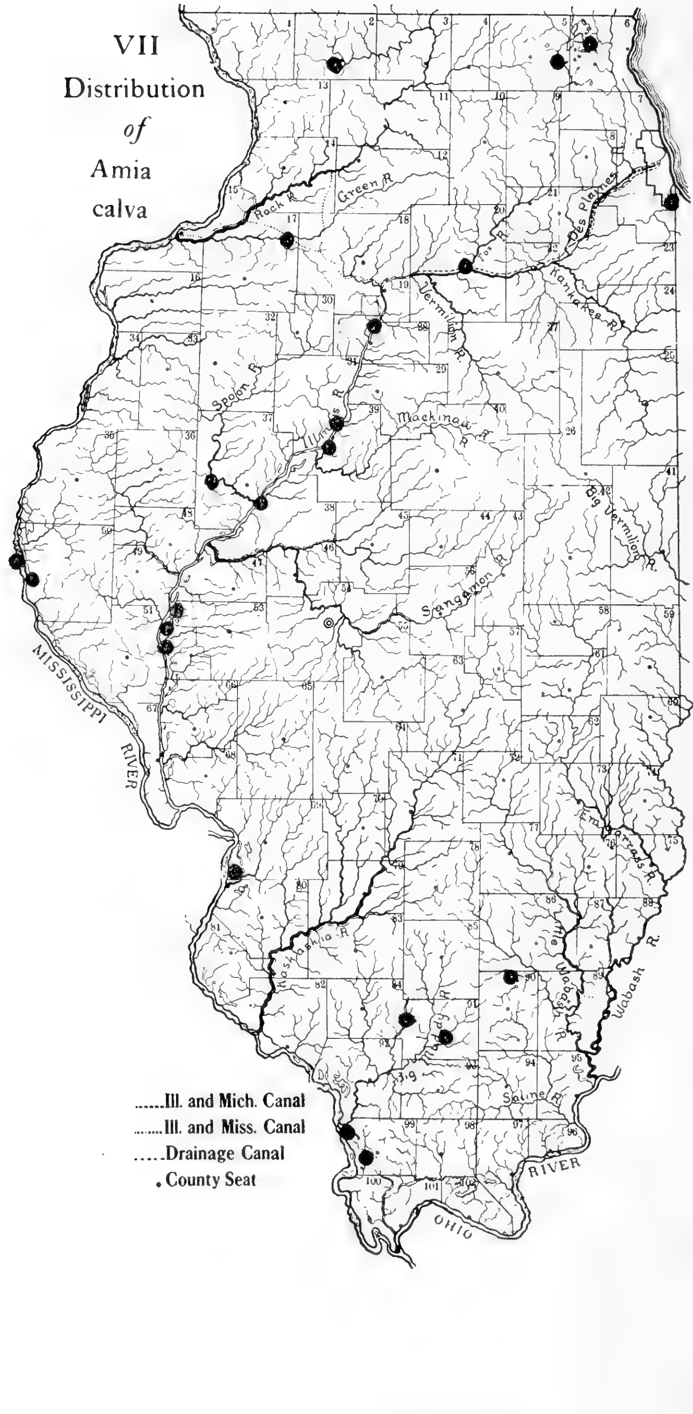

IV
Water Courses
and
Distribution
of
Collections
Illinois and Michigan Canal
Illinois and Mississippi Canal
Drainage Canal
County Seat
MISSISSIPPI
RIVER
OHIO
Rock R.
Green R.
Fox R.
Des Plaines
Kankakee R.
Vermilion R.
Spoon R.
Illinois R.
Mackinaw
Sangamon R.
Big Vermilion R.
Embarrass
Wabash R.
Kaskaskia
Lit. Wabash R.
Big Muddy R.
Saline R.




V
Distribution
*of*
Lepisosteus
osseus

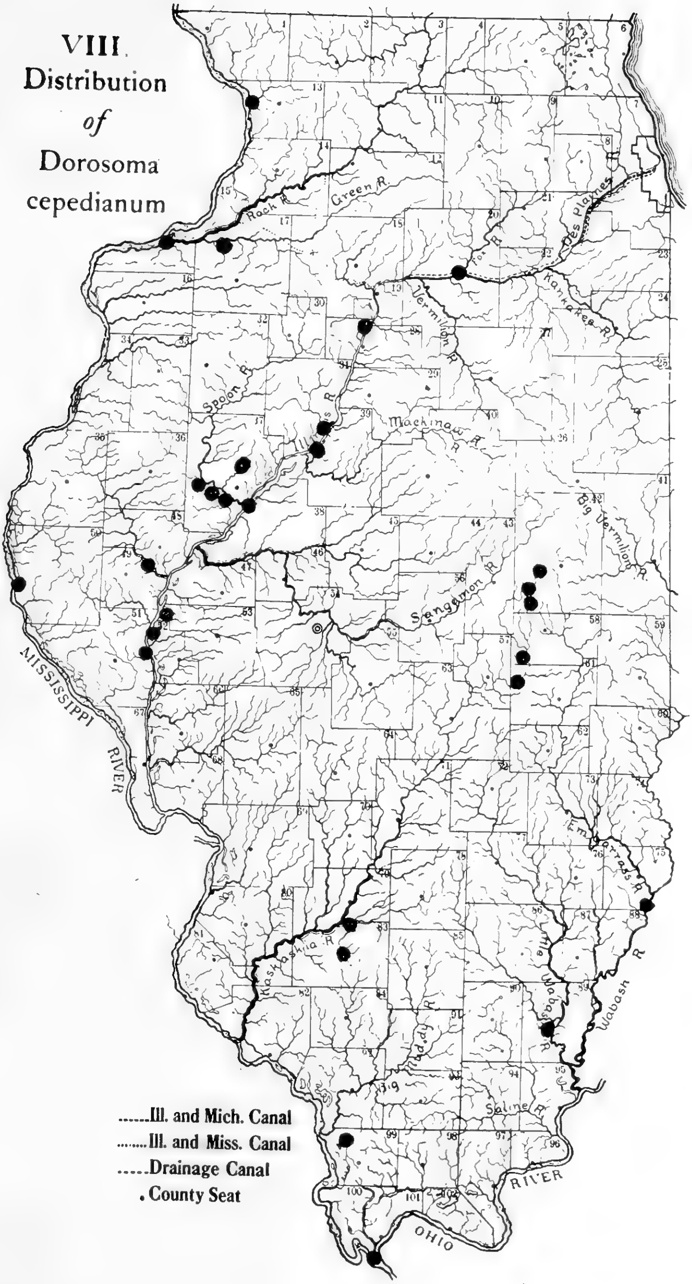



VI
Distribution
*of*
Lepisosteus platostomus

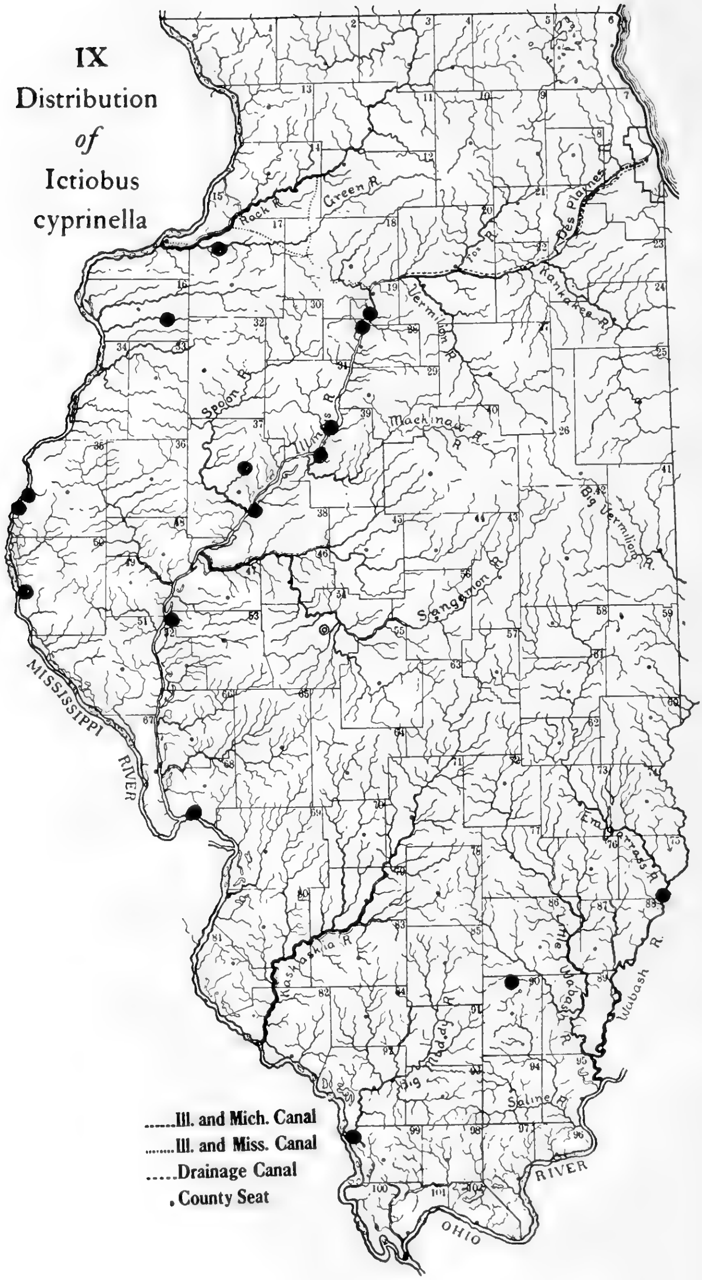


VII
Distribution
of
Amia
calva
Rock R.
Green R.
Fox R.
Des Plaines
Kankakee R.
Vermilion R.
Spoon R.
Illinois R.
Mackinaw R.
Big Vermilion R.
Sangamon R.
MISSISSIPPI
RIVER
Embarras R.
Kaskaskia R.
Wabash R.
Little Wabash R.
Big Muddy R.
Saline R.
OHIO
RIVER
......Ill. and Mich. Canal
........Ill. and Miss. Canal
.....Drainage Canal
. County Seat

VIII.
Distribution
*of*
Dorosoma
cepedianum



# IX
Distribution
*of*
Ictiobus
cyprinella



X

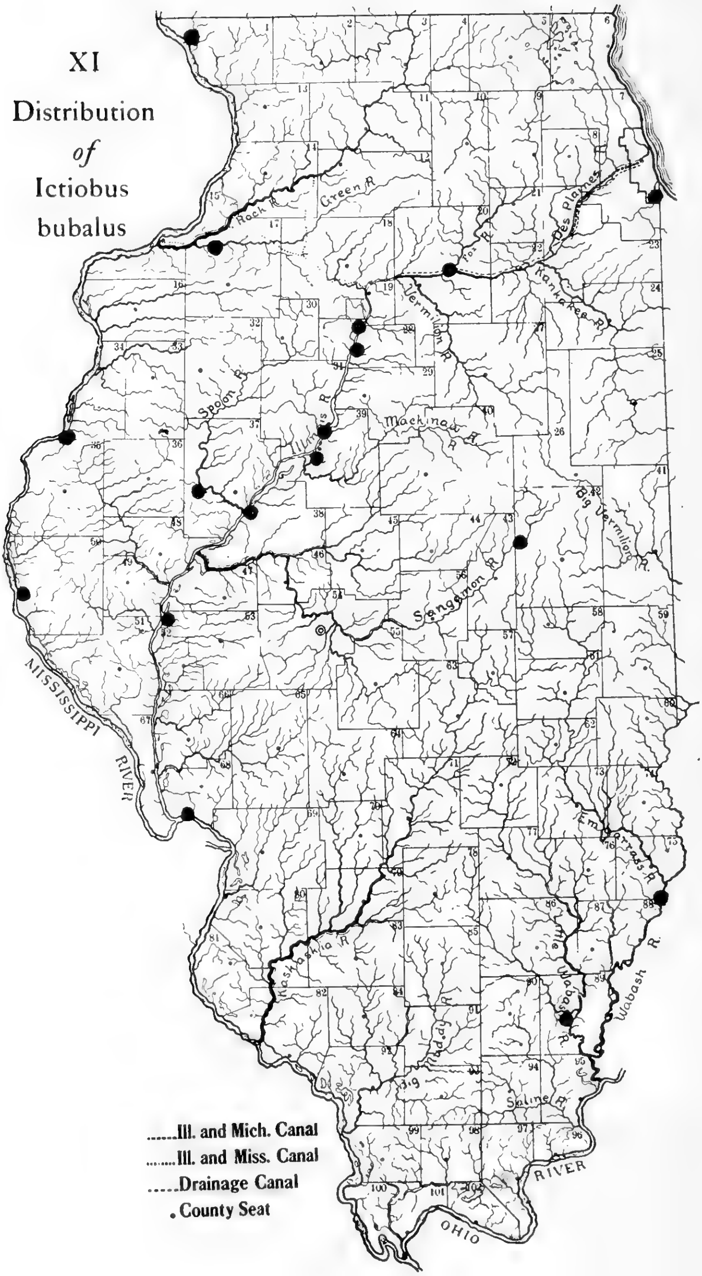
Distribution

*of*

Ictiobus

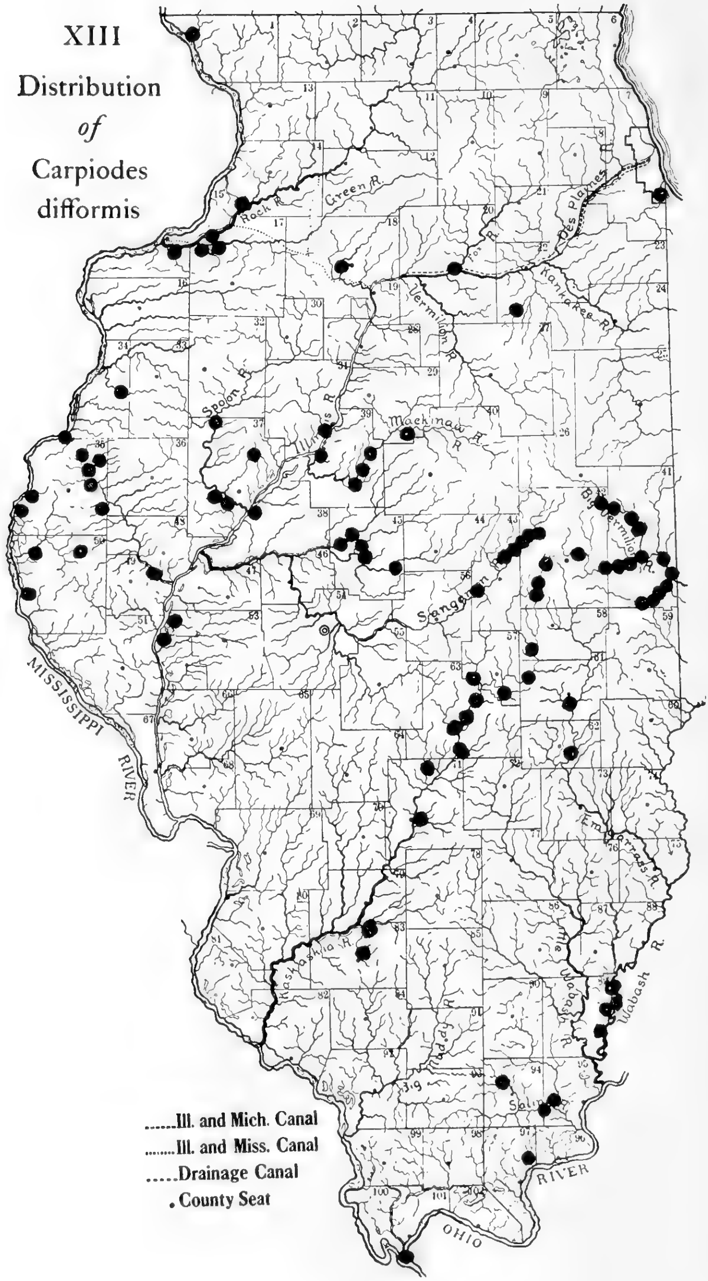
urus

# XI
## Distribution *of* Ictiobus bubalus



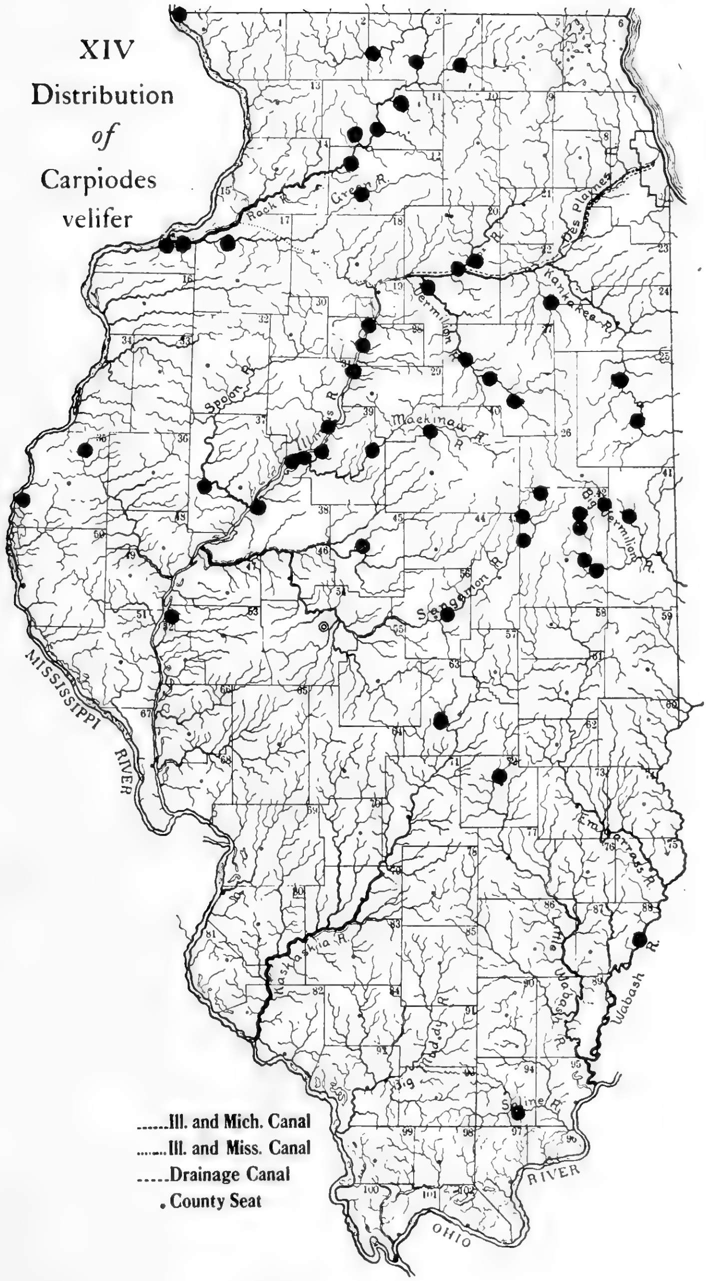
XII
Distribution
*of*
Carpiodes
carpio


......Ill. and Mich. Canal
........Ill. and Miss. Canal
.....Drainage Canal
. County Seat

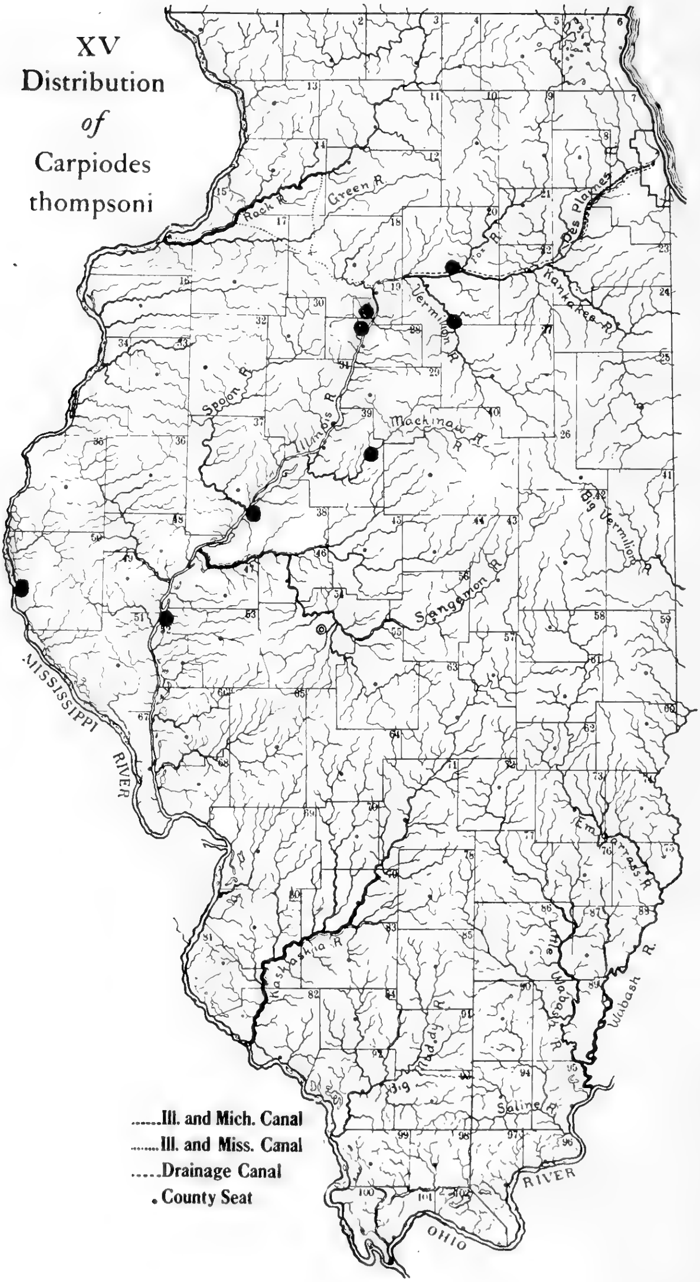


XIII
Distribution
of
Carpiodes
difformis
Rock R.
Green R.
Des Plaines
Kankakee R.
Vermilion R.
Spoon R.
Illinois R.
Mackinaw R.
Big Vermilion R.
Sangamon
MISSISSIPPI
RIVER
Kaskaskia R.
Little Wabash R.
Wabash R.
Big Muddy R.
Saline R.
OHIO
RIVER
......Ill. and Mich. Canal
........Ill. and Miss. Canal
.....Drainage Canal
• County Seat

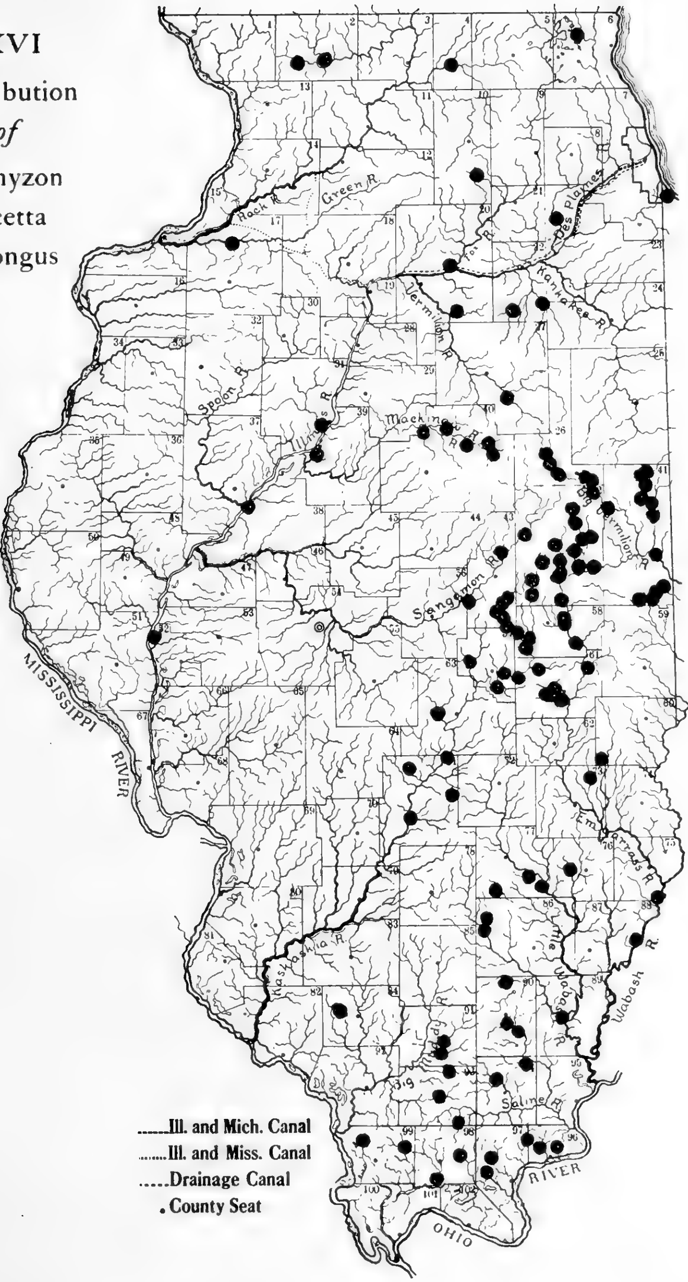
# XIV
Distribution
*of*
Carpiodes
velifer



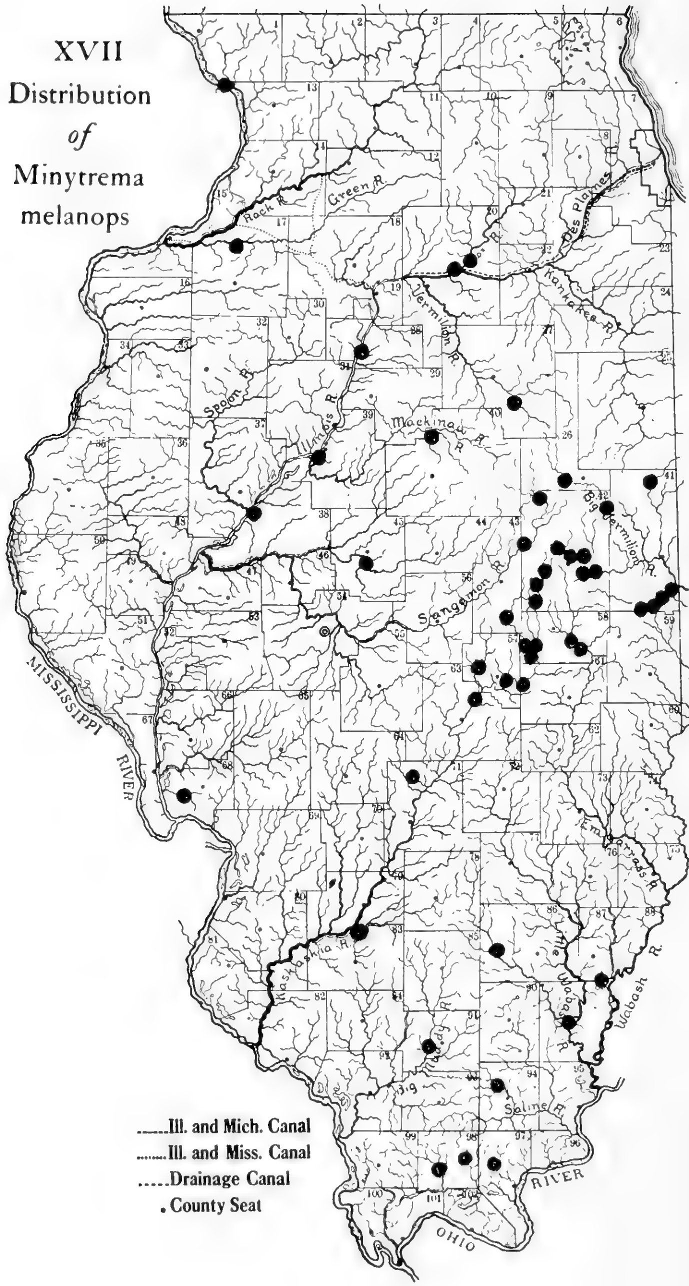
XV
Distribution
*of*
Carpiodes
thompsoni

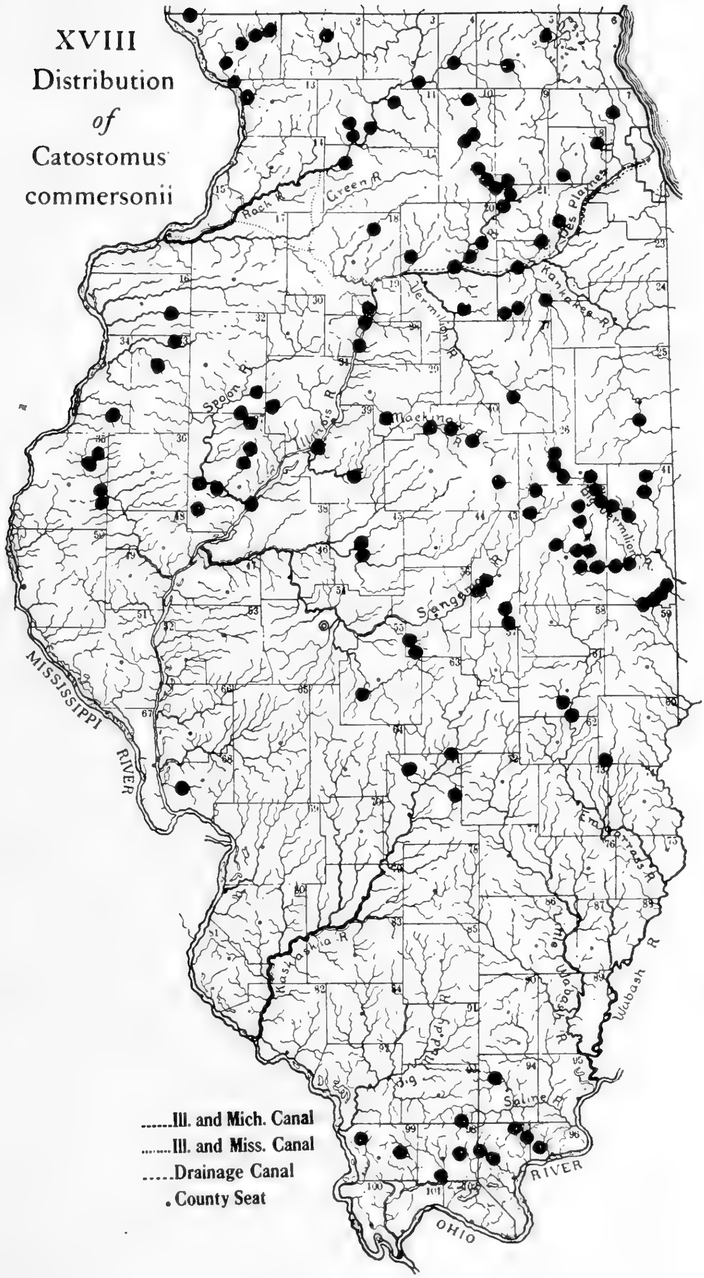


XVI
Distribution
*of*
Erimyzon
sucetta
oblongus

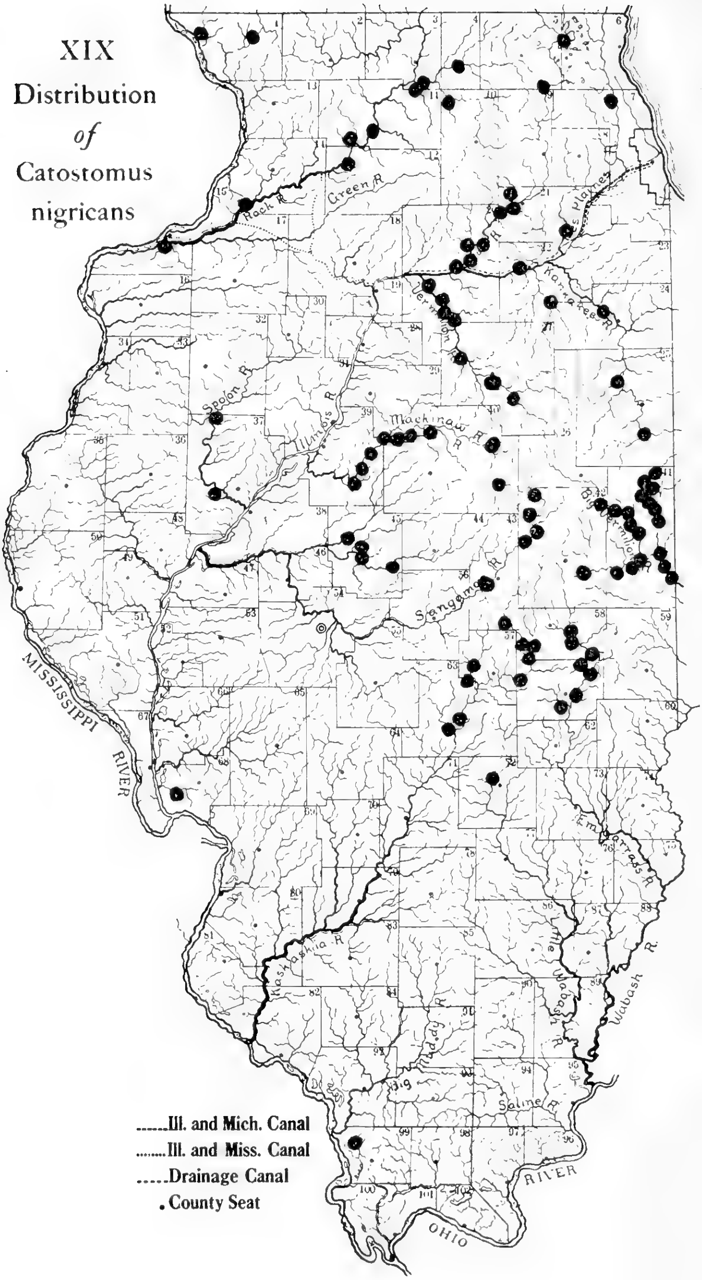


# XVII
Distribution
*of*
Minytrema
melanops

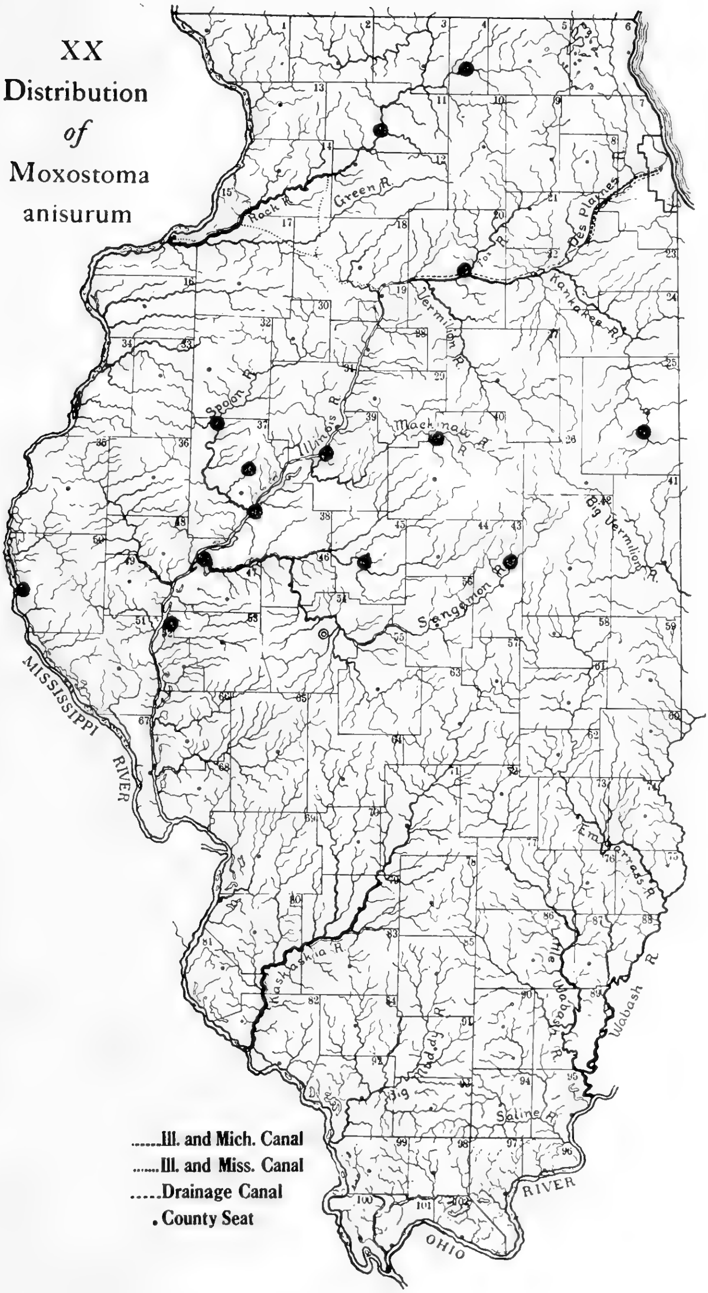




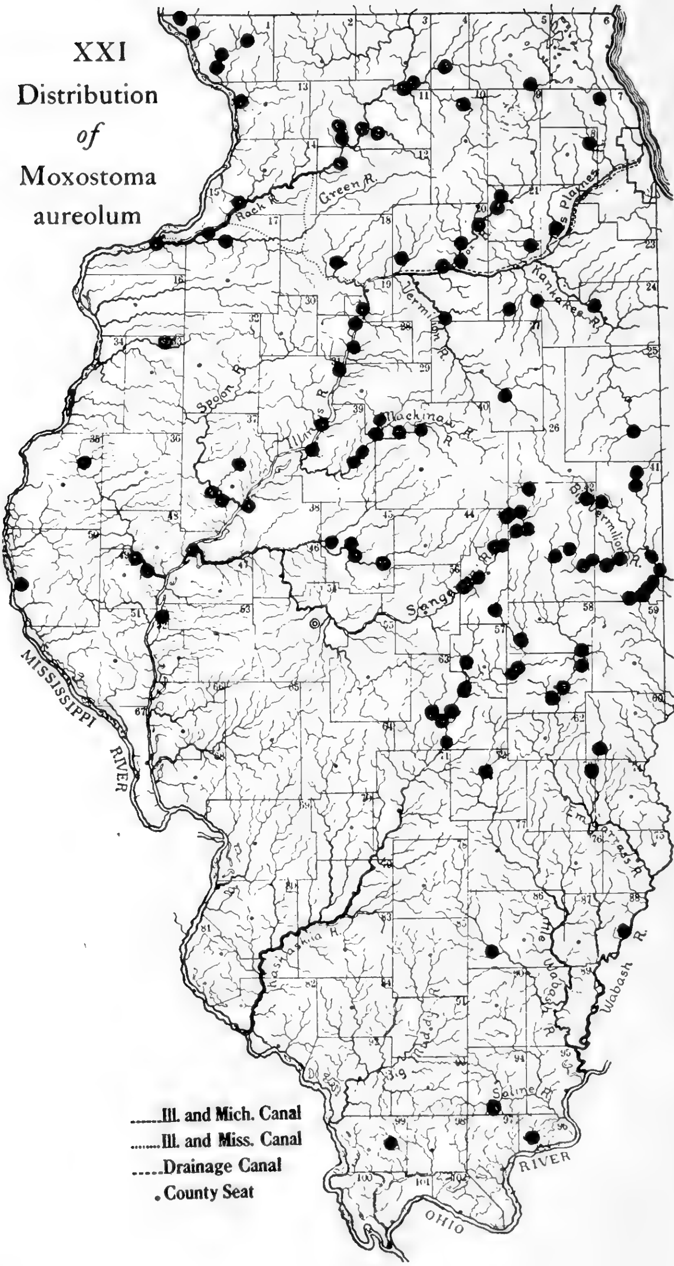

XVIII
Distribution
*of*
Catostomus
commersonii

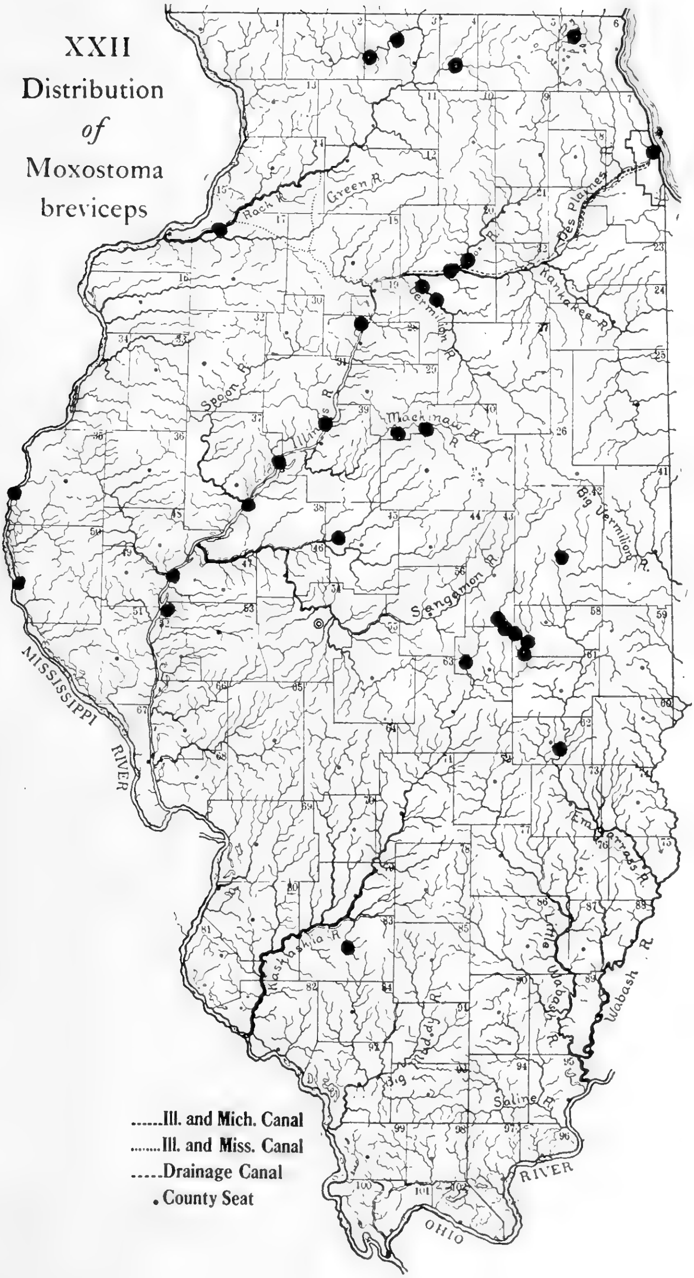

XIX
Distribution
of
Catostomus
nigricans
MISSISSIPPI
RIVER
OHIO
RIVER
Rock R.
Green R.
Illinois R.
Spoon R.
Mackinaw R.
Sangamon R.
Vermilion R.
Kankakee R.
Des Plaines
Kaskaskia R.
Wabash R.
Saline R.
Big Muddy R.
......Ill. and Mich. Canal
........Ill. and Miss. Canal
.....Drainage Canal
. County Seat

## XX
## Distribution *of* Moxostoma anisurum



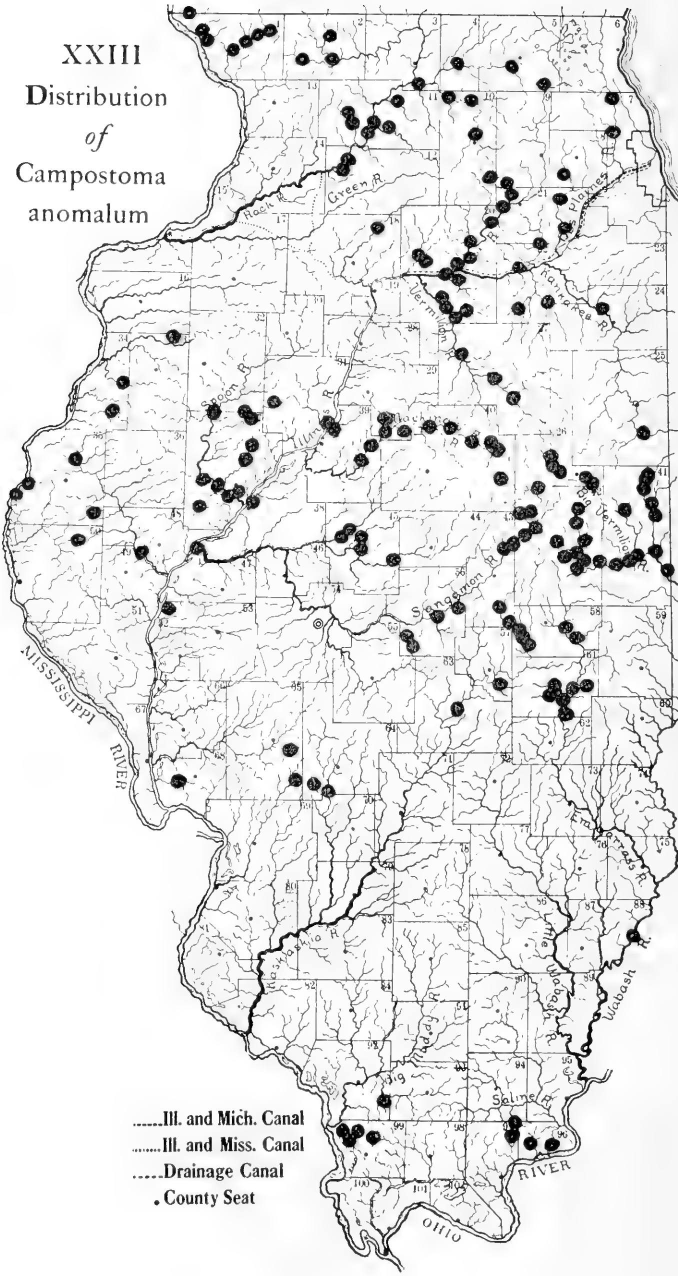
XXI
Distribution
*of*
Moxostoma
aureolum



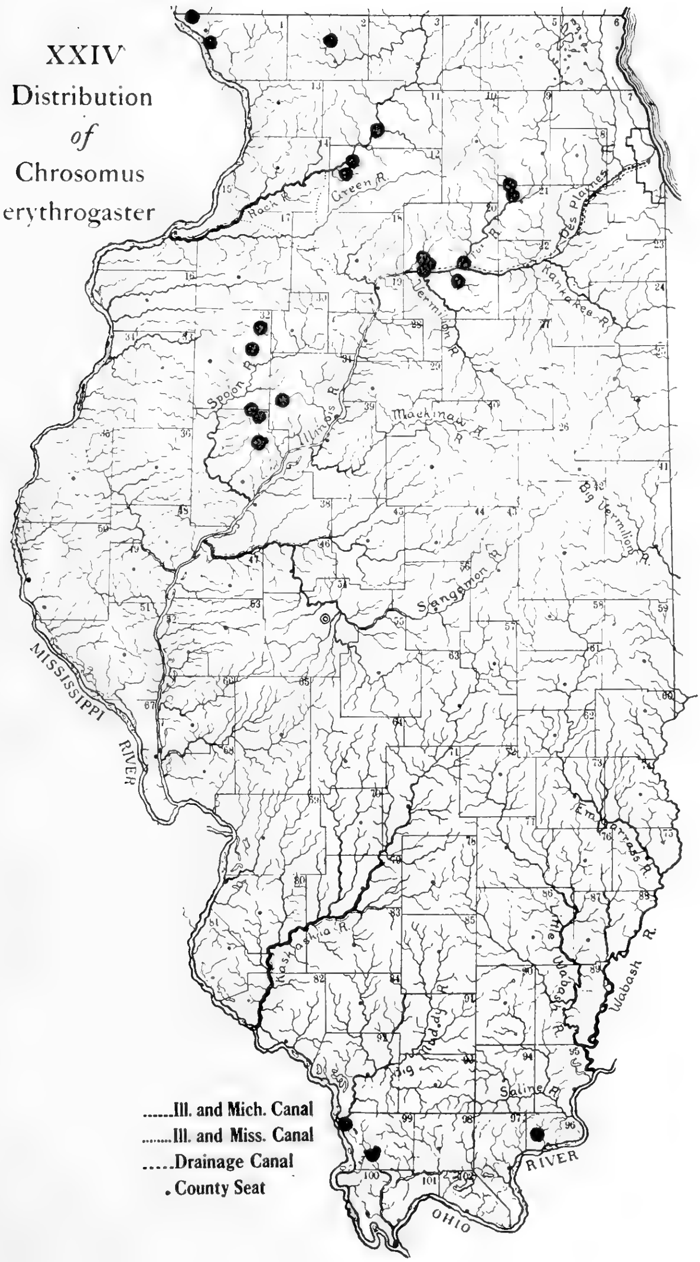



XXII
Distribution
*of*
Moxostoma
breviceps

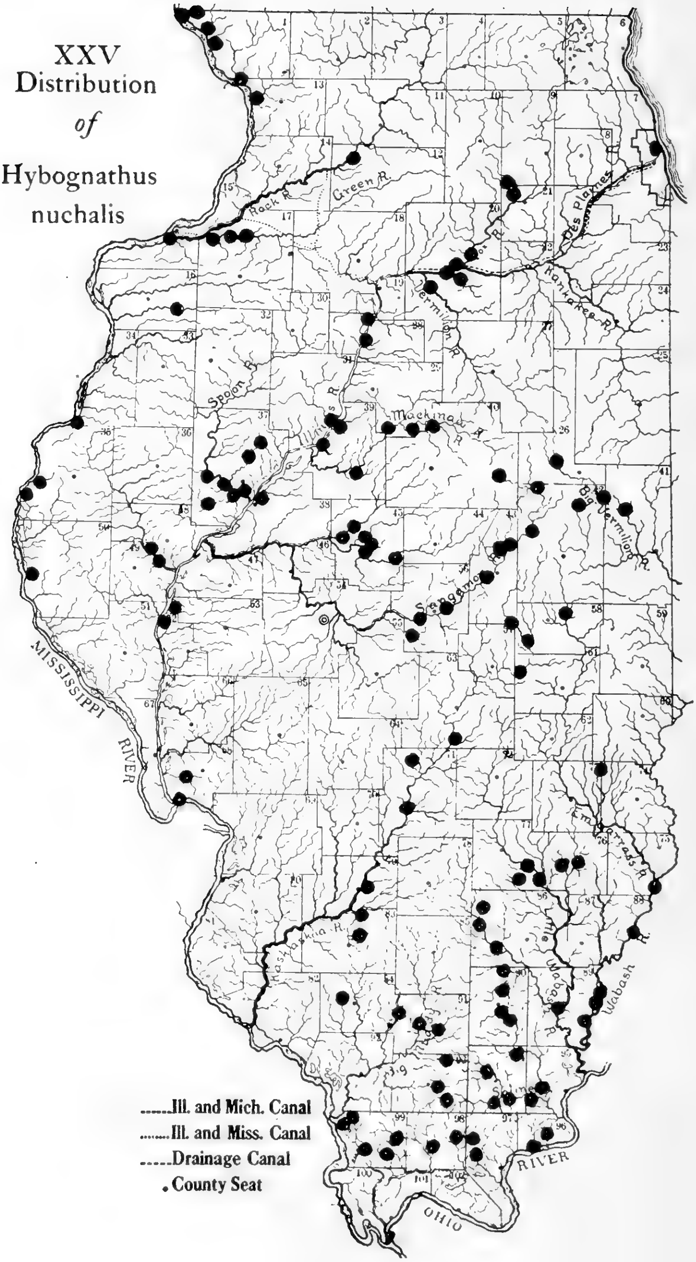
XXIII
Distribution
*of*
Campostoma
anomalum



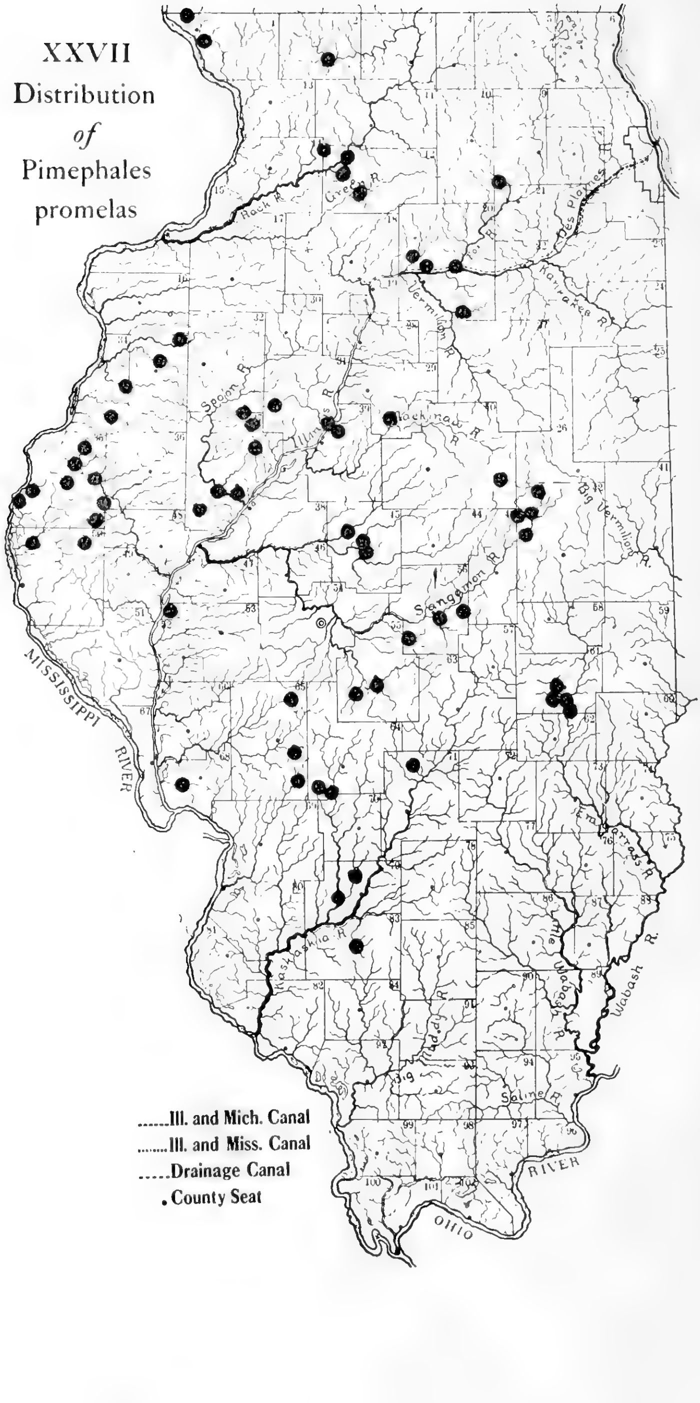

......Ill. and Mich. Canal
.........Ill. and Miss. Canal
.....Drainage Canal
. County Seat


XXIV
Distribution
of
Chrosomus
erythrogaster
Rock R.
Green R.
Des Plaines
Kankakee R.
Vermilion R.
Spoon R.
Illinois R.
Mackinaw R.
Big Vermilion R.
Sangamon R.
MISSISSIPPI
RIVER
Embarrass R.
Wabash R.
Little Wabash R.
Kaskaskia R.
Big Muddy R.
Saline R.
RIVER
OHIO
......Ill. and Mich. Canal
........Ill. and Miss. Canal
.....Drainage Canal
. County Seat

# XXV
Distribution
*of*
Hybognathus
nuchalis

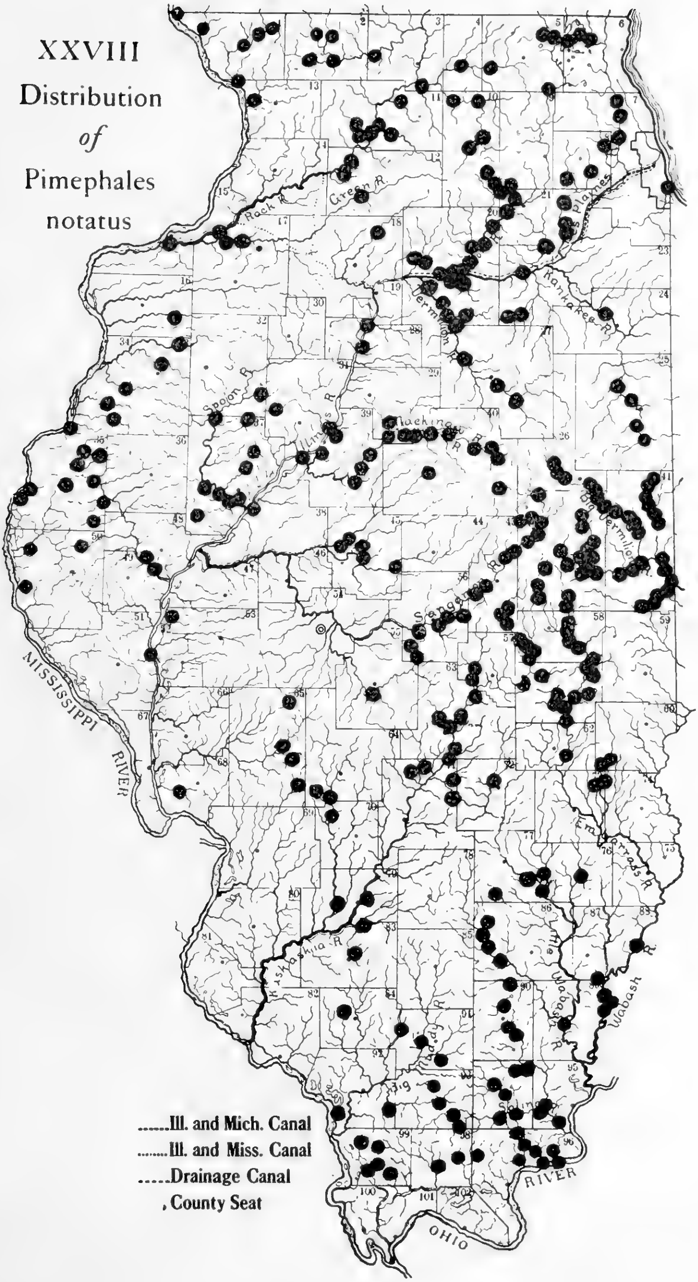


XXVI
Distribution
*of*
Hybognathus
nubila

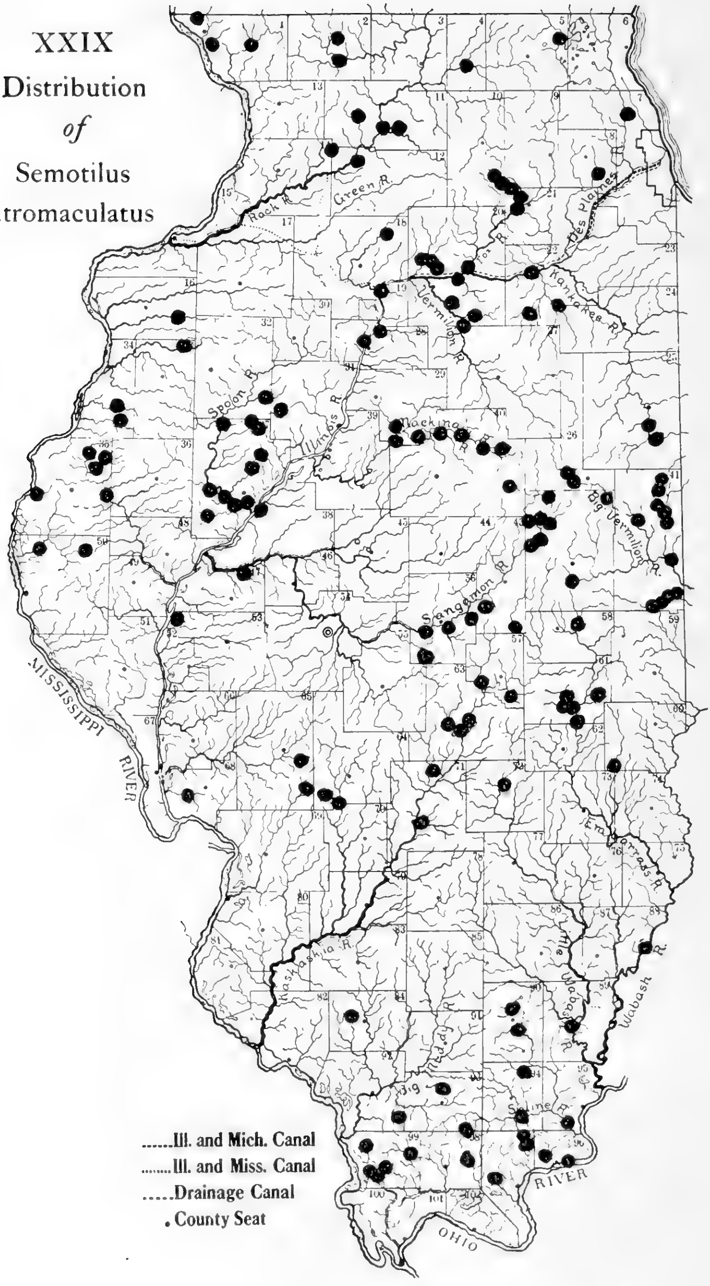


XXVII
Distribution
of
Pimephales
promelas
Rock R.
Green R.
Des Plaines R.
Kankakee R.
Vermilion R.
Spoon R.
Illinois R.
Mackinaw R.
Big Vermilion R.
Sangamon R.
MISSISSIPPI RIVER
Embarrass R.
Kaskaskia R.
Little Wabash R.
Wabash R.
Big Muddy R.
Saline R.
OHIO RIVER
......Ill. and Mich. Canal
........Ill. and Miss. Canal
.....Drainage Canal
. County Seat

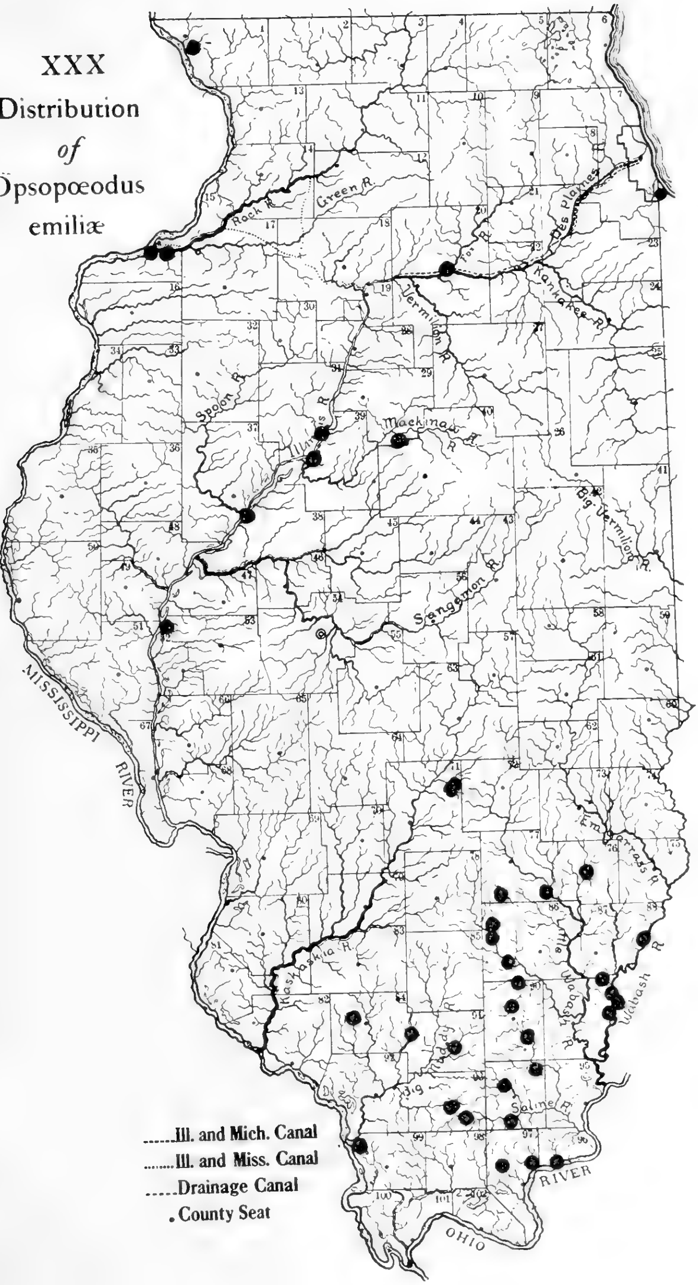
XXVIII
Distribution
*of*
Pimephales
notatus

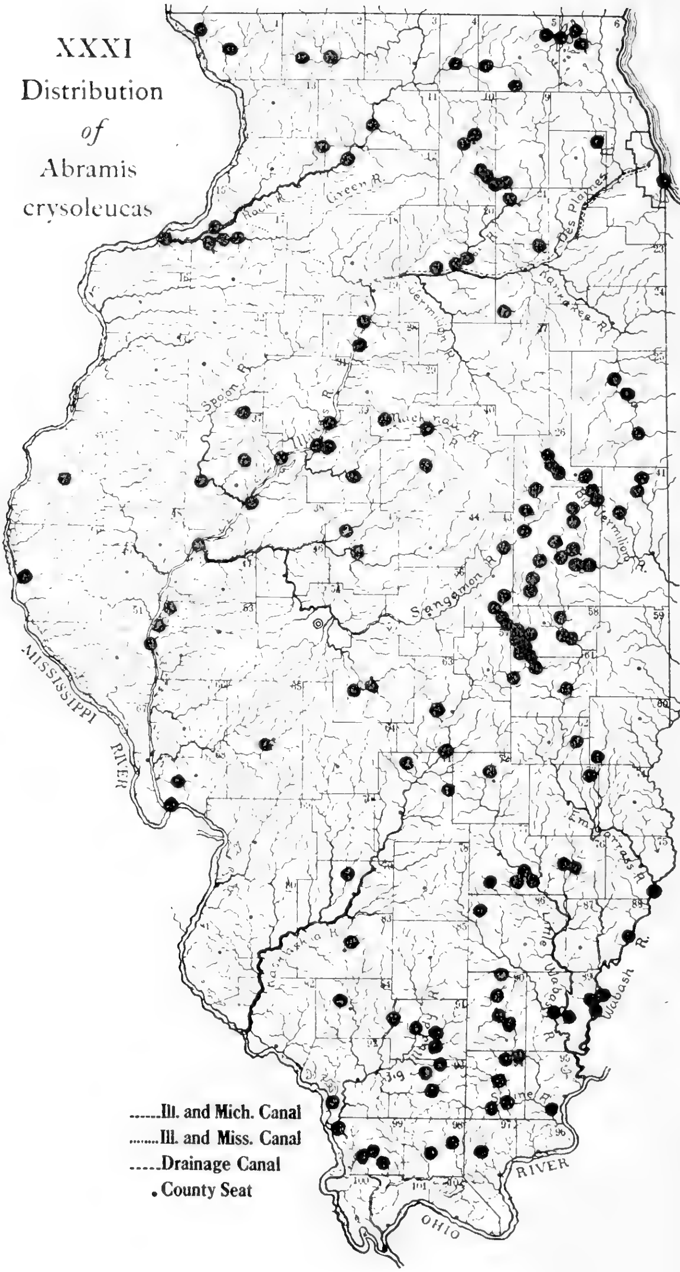


## XXIX Distribution *of* Semotilus atromaculatus



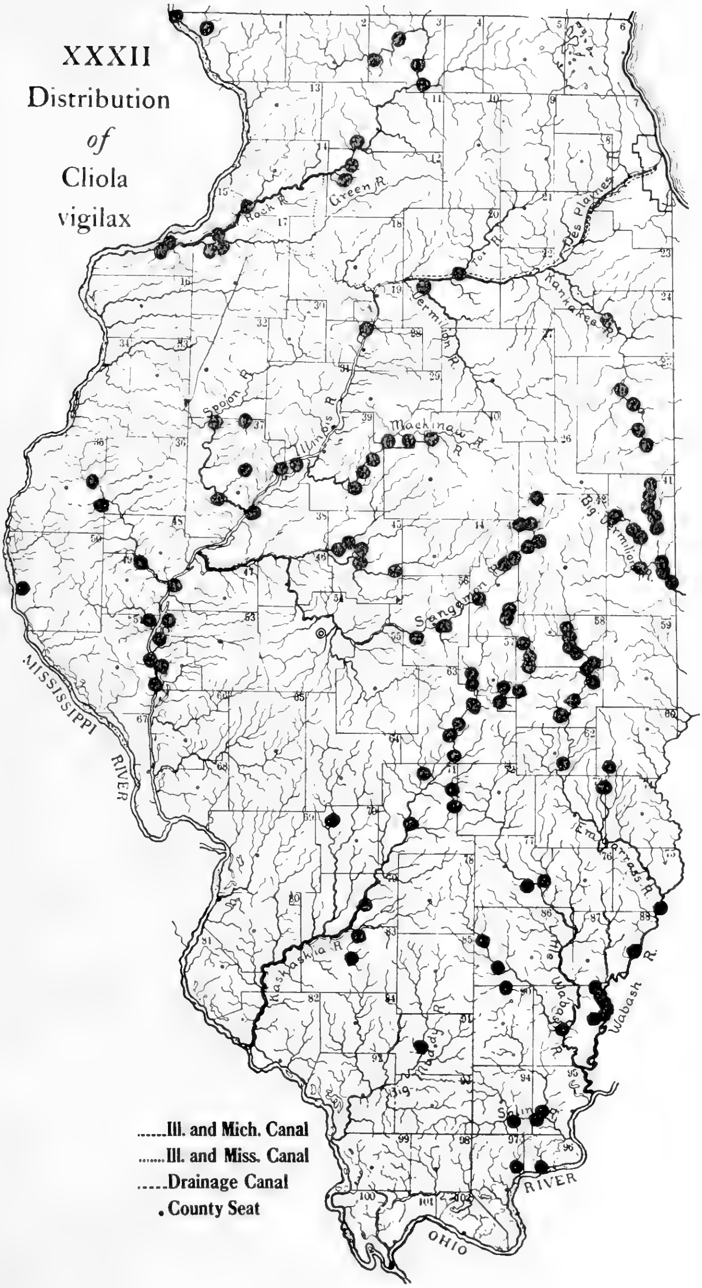
XXX
Distribution
*of*
Öpsopœodus
emiliæ

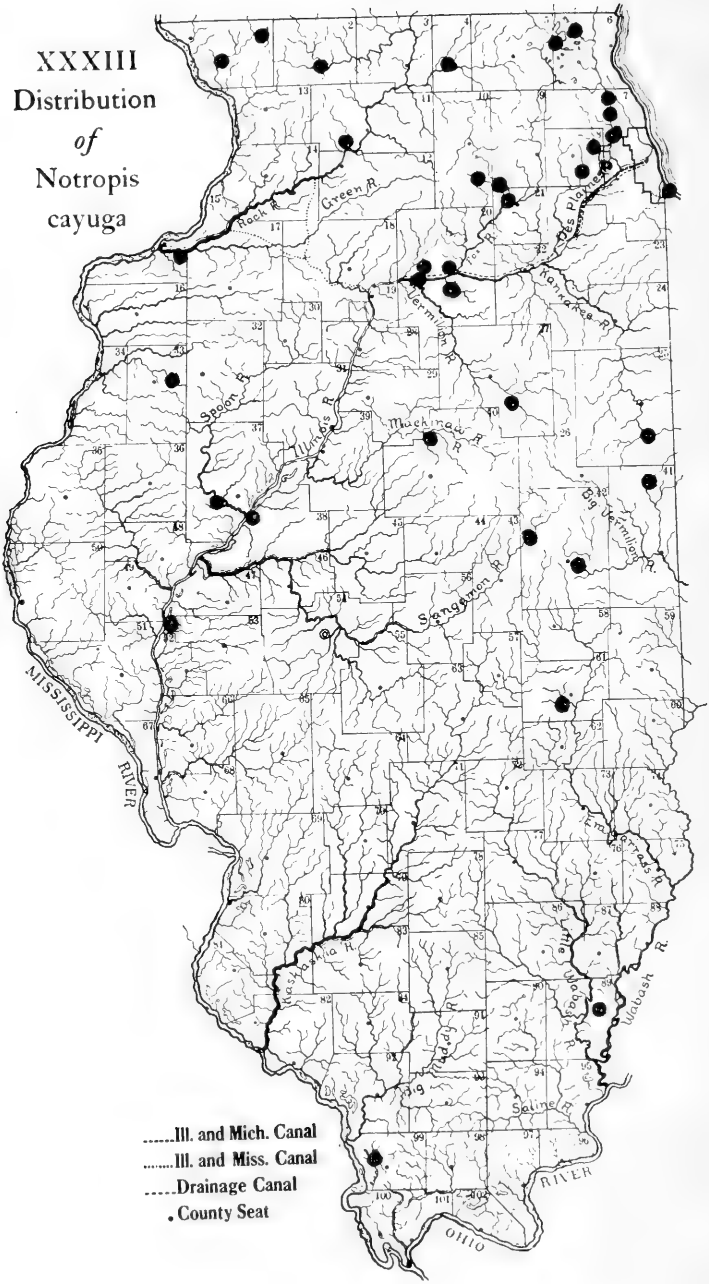





## XXXI
## Distribution *of* Abramis crysoleucas

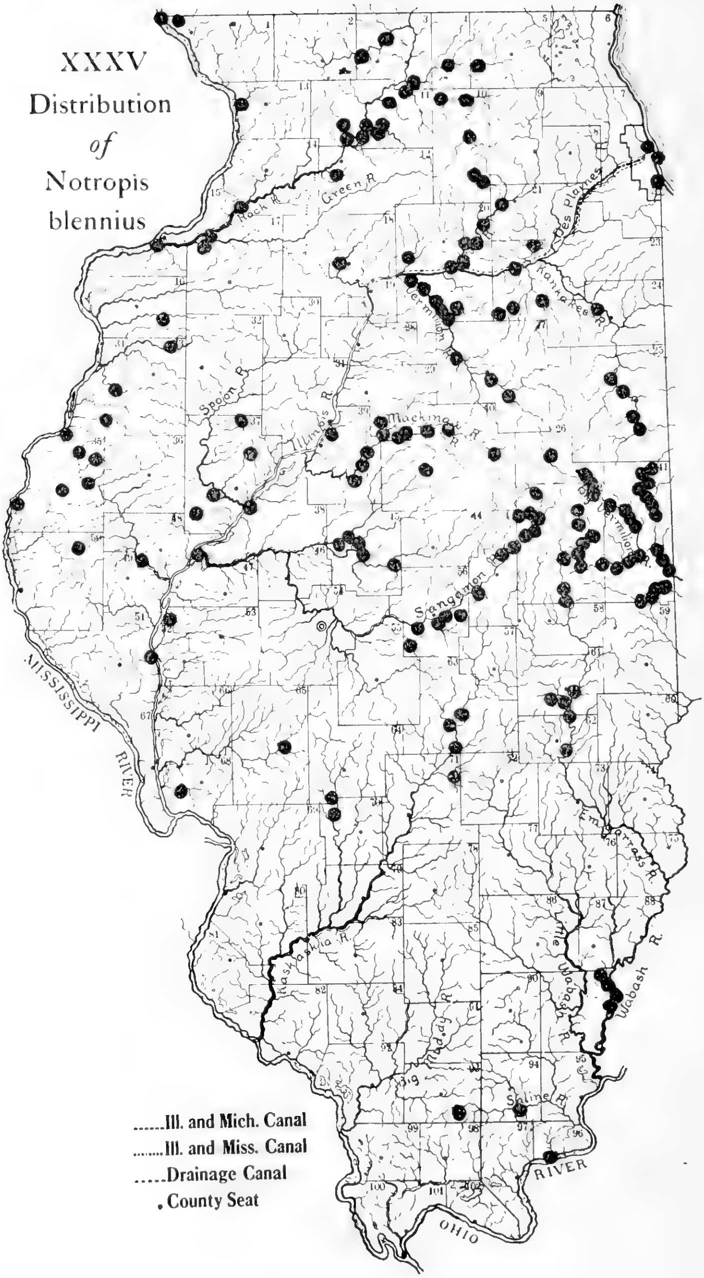
XXXII
Distribution
*of*
Cliola
vigilax



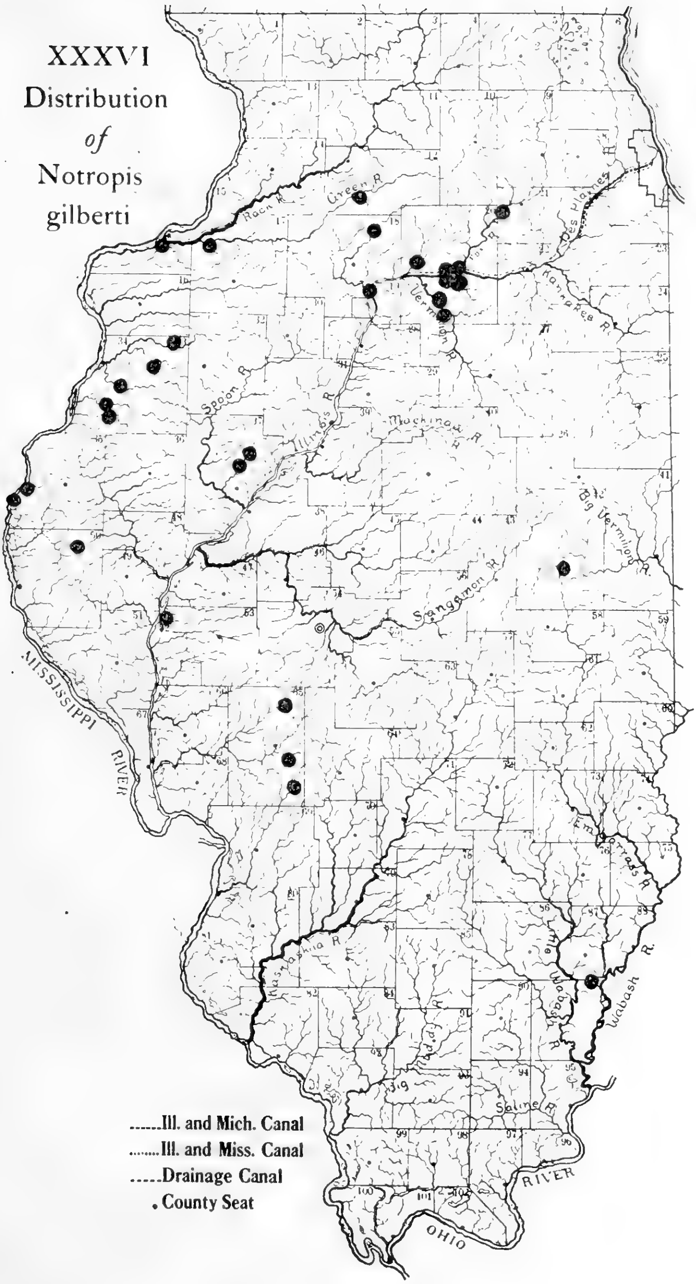


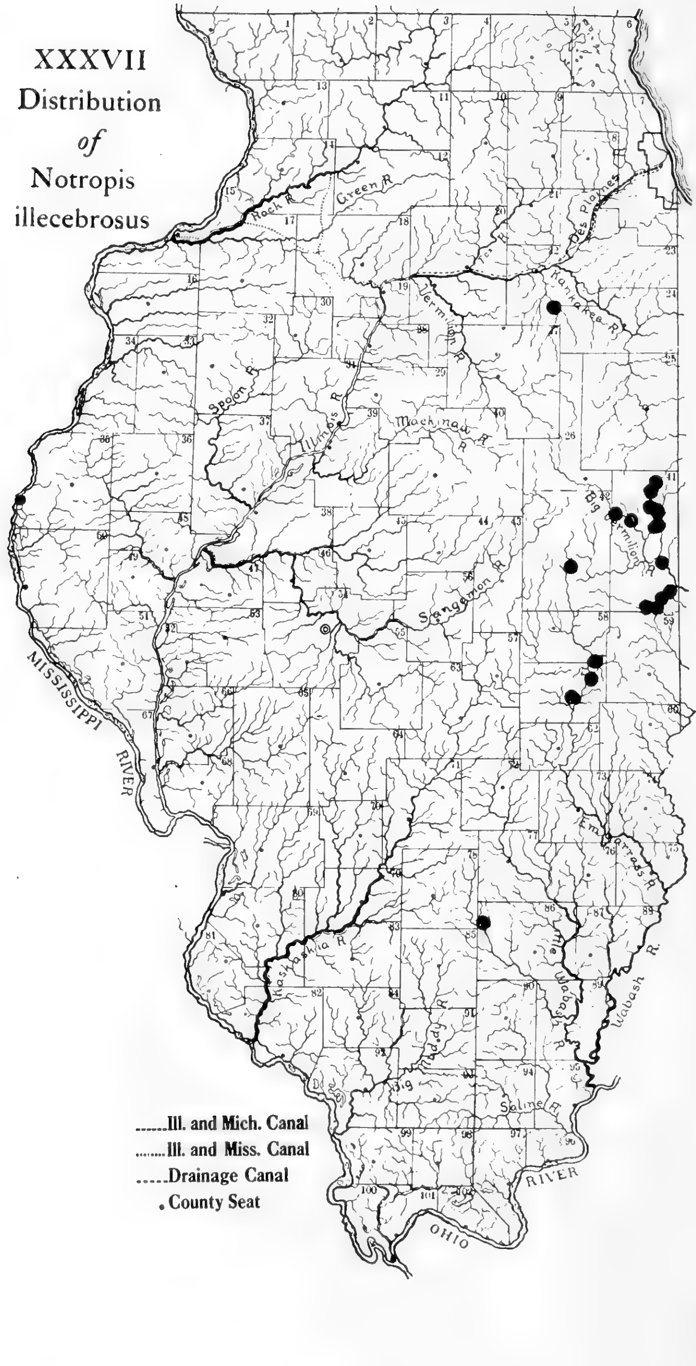

XXXIII
Distribution
*of*
Notropis
cayuga

# XXXIV
## Distribution *of* Notropis heterodon


XXXV
Distribution
of
Notropis
blennius
Rock R.
Green R.
Des Plaines
Kankakee R.
Vermilion R.
Spoon R.
Illinois R.
Mackinaw R.
Sangamon R.
Vermilion
MISSISSIPPI
RIVER
Kaskaskia R.
Big Muddy R.
Little Wabash R.
Wabash R.
Saline R.
RIVER
OHIO
......Ill. and Mich. Canal
........Ill. and Miss. Canal
.....Drainage Canal
. County Seat

XXXVI
Distribution
*of*
Notropis
gilberti

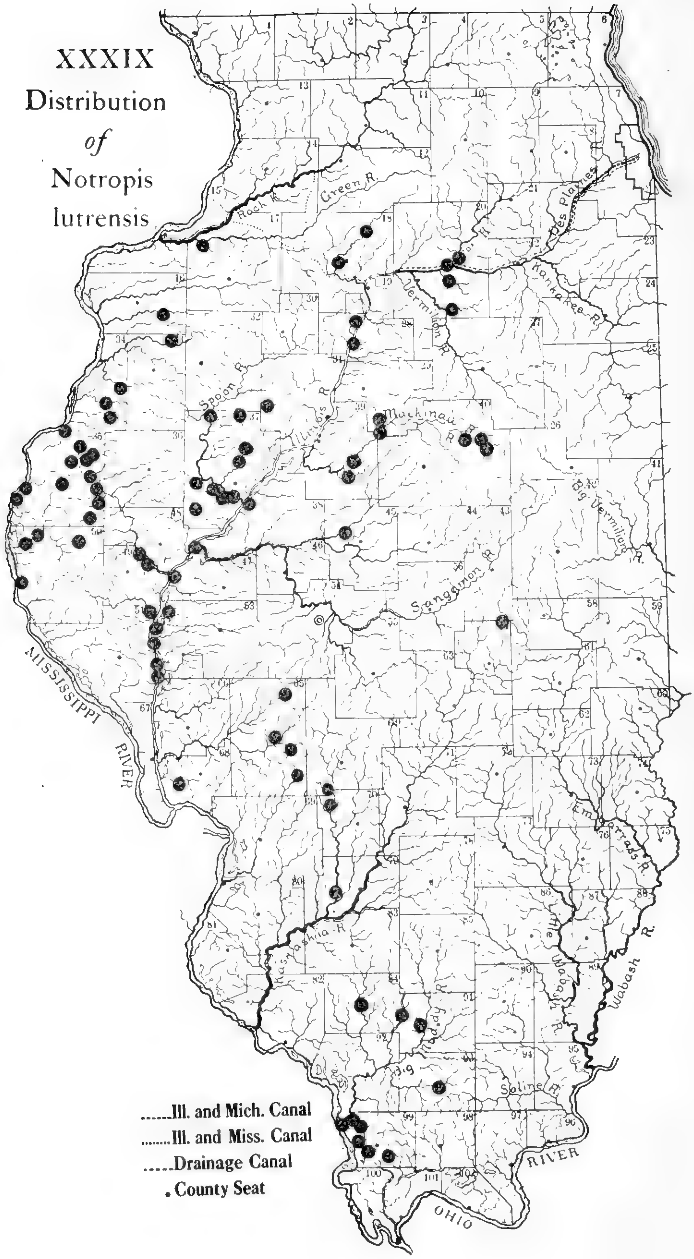




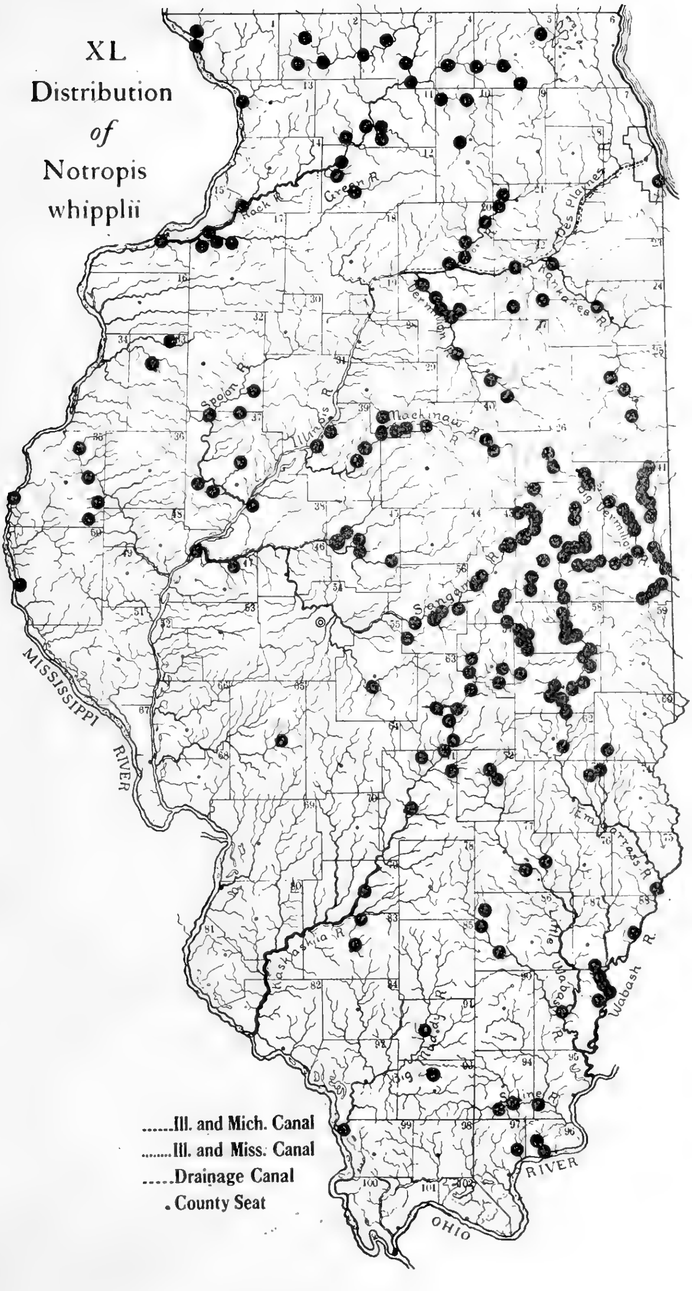

XXXVII
Distribution
*of*
Notropis
illecebrosus

XXXVIII
Distribution
*of*
Notropis
hudsonius

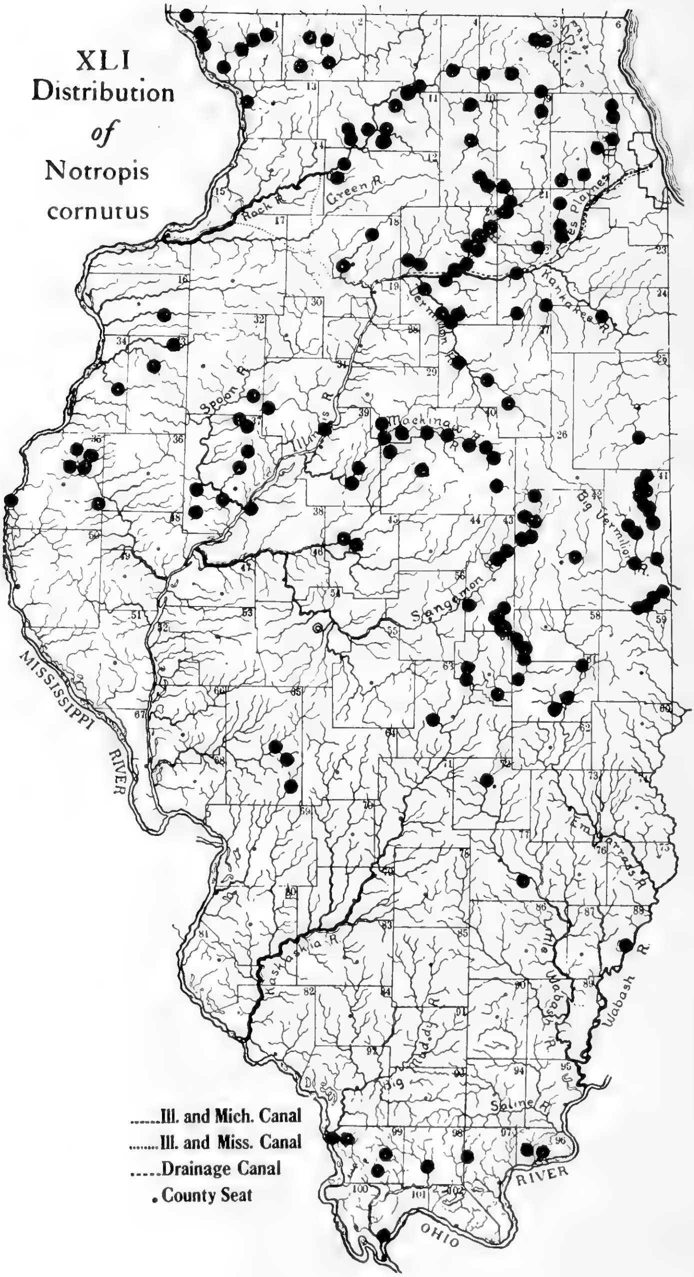

......Ill. and Mich. Canal
........Ill. and Miss. Canal
.....Drainage Canal
. County Seat


XXXIX
Distribution
of
Notropis
lutrensis
Rock R.
Green R.
Des Plaines
Kankakee R.
Vermilion R.
Spoon R.
Illinois R.
Mackinaw R.
Big Vermilion R.
Sangamon R.
MISSISSIPPI
RIVER
Kaskaskia R.
Little Wabash R.
Wabash R.
Big Muddy R.
Saline R.
OHIO
RIVER
.......Ill. and Mich. Canal
........Ill. and Miss. Canal
.....Drainage Canal
• County Seat

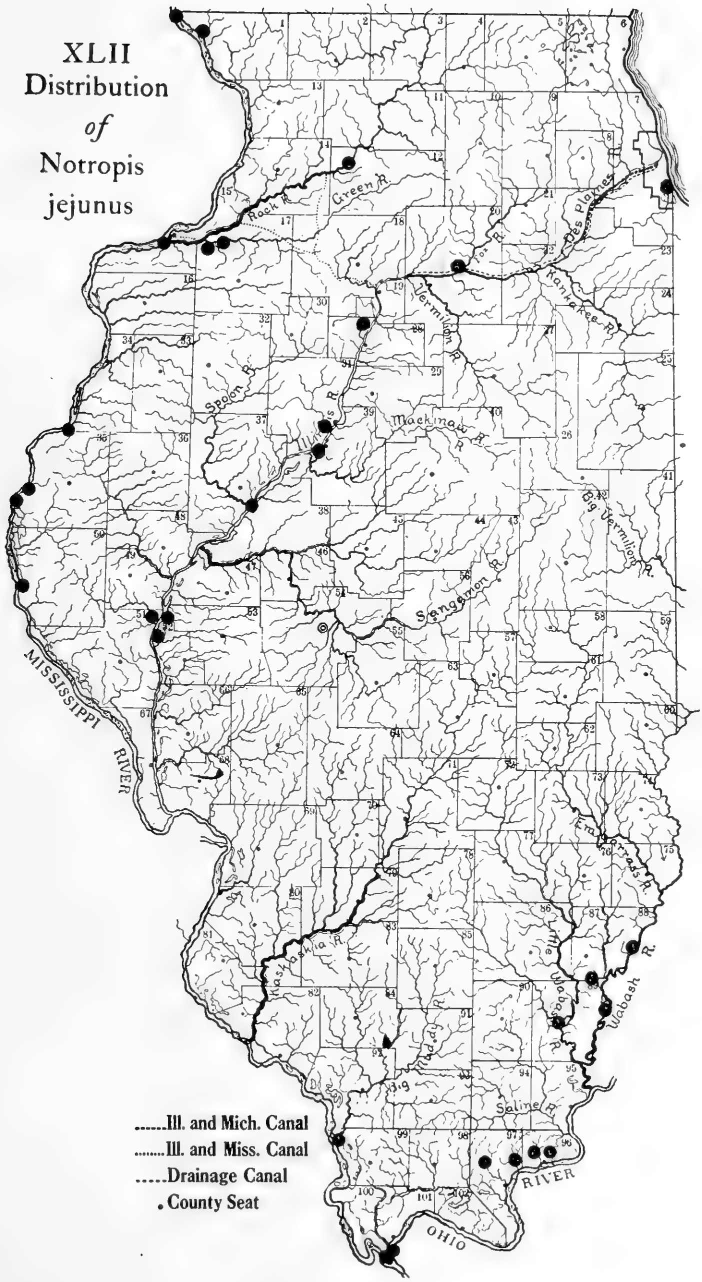
XL
Distribution
*of*
Notropis
whipplii

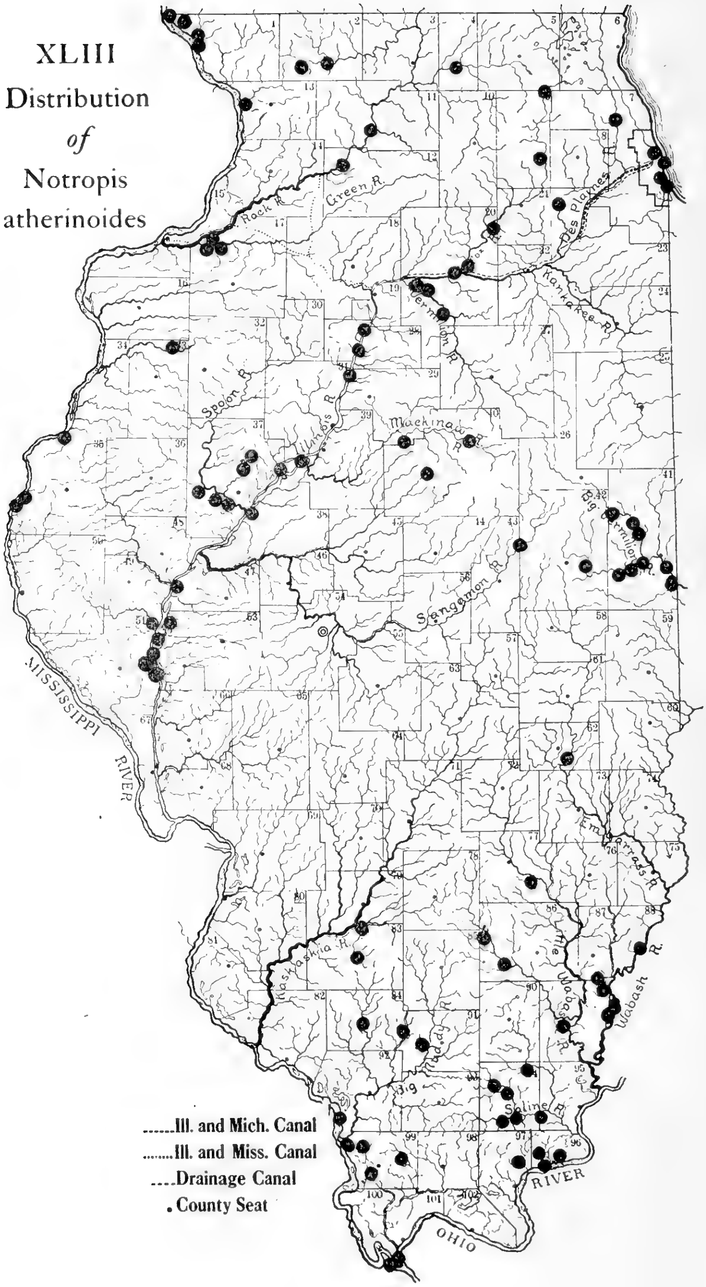


# XLI
# Distribution *of* Notropis cornutus



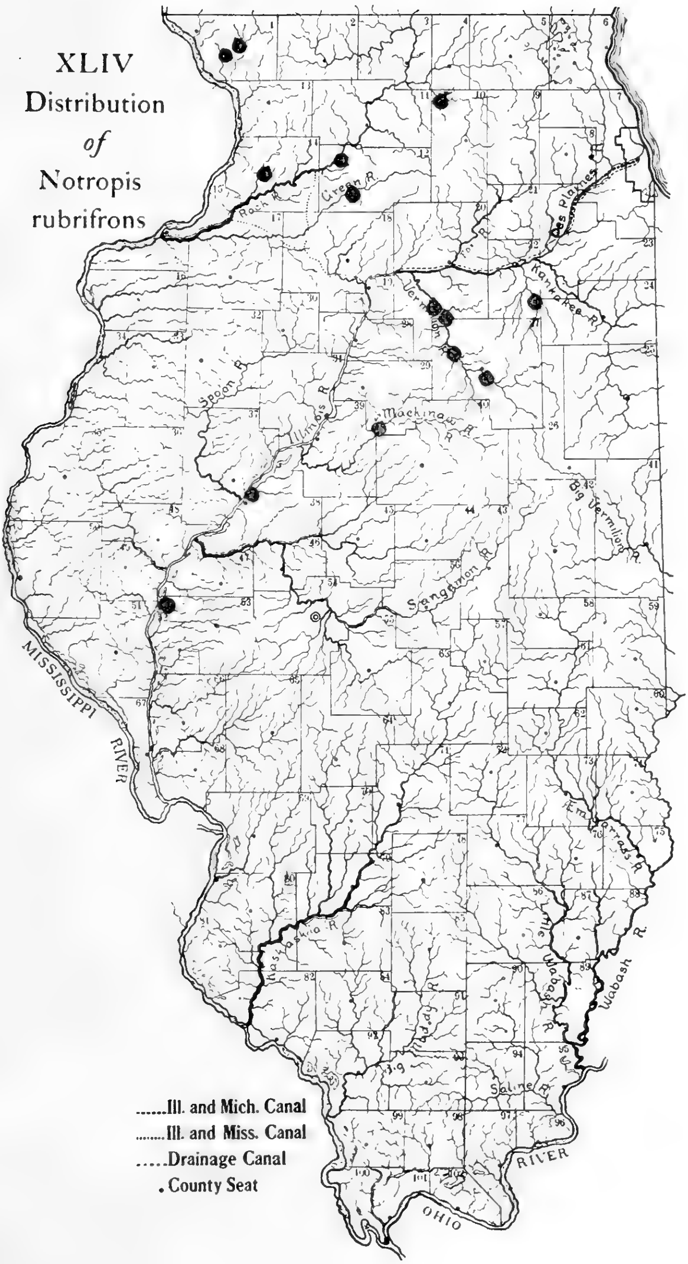
XLII Distribution *of* Notropis jejunus

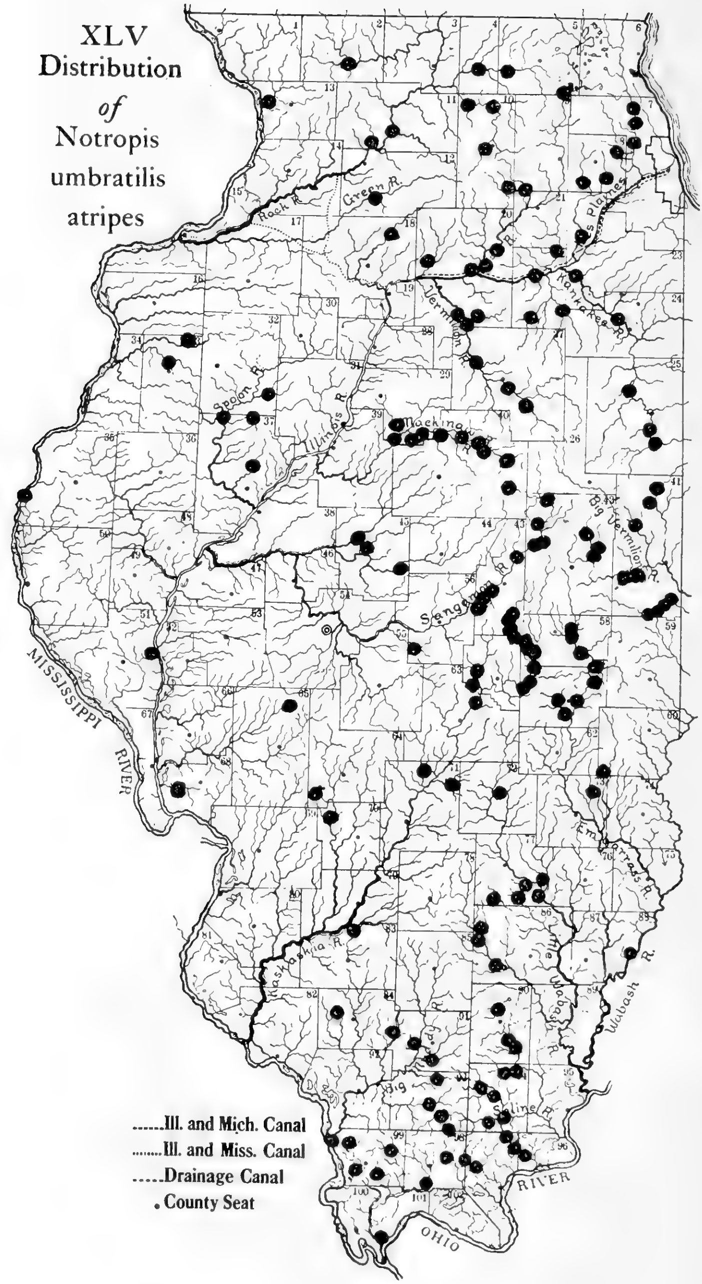





XLIII
Distribution
*of*
Notropis
atherinoides

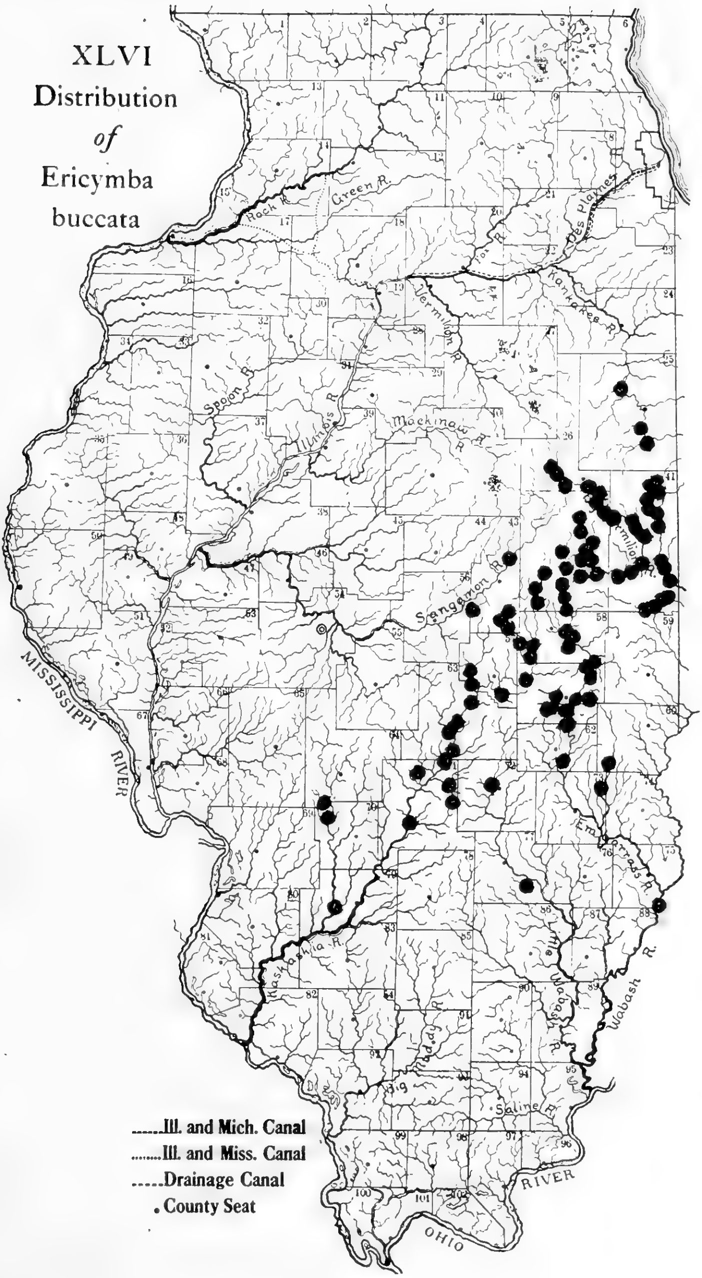
XLIV
Distribution
*of*
Notropis
rubrifrons



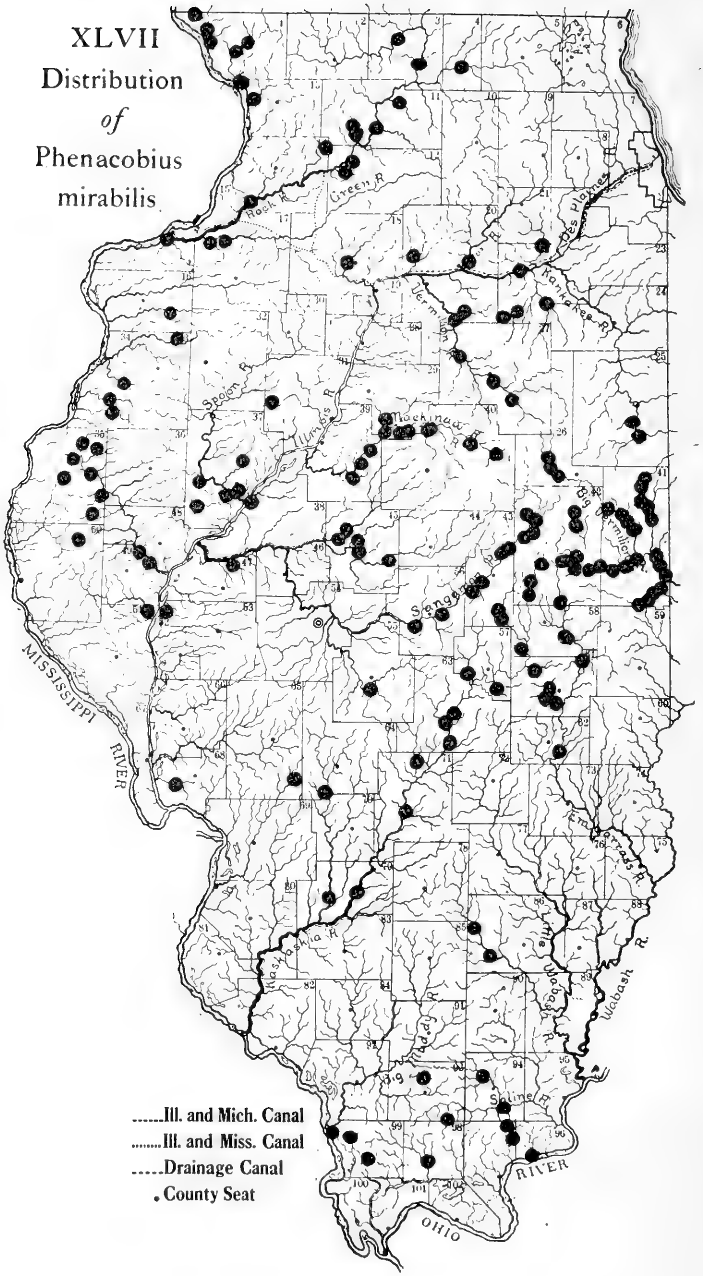



XLV
Distribution
*of*
Notropis
umbratilis
atripes

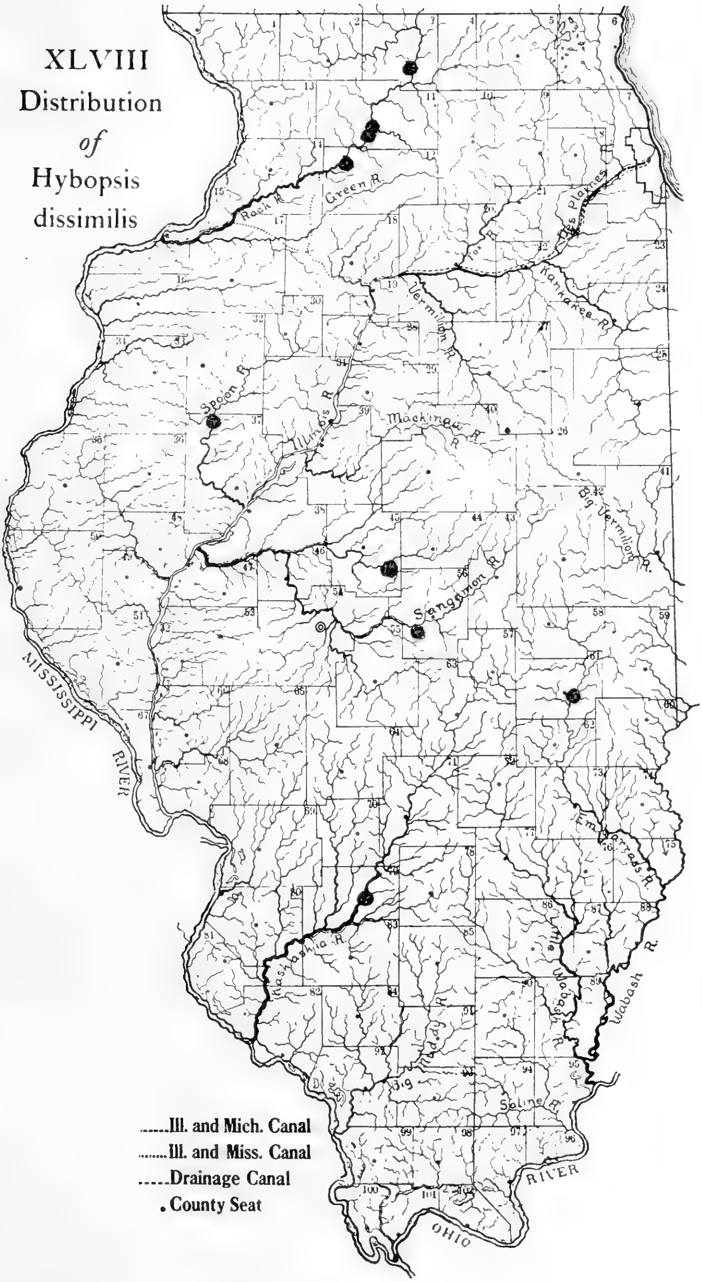
XLVI
Distribution
*of*
Ericymba
buccata

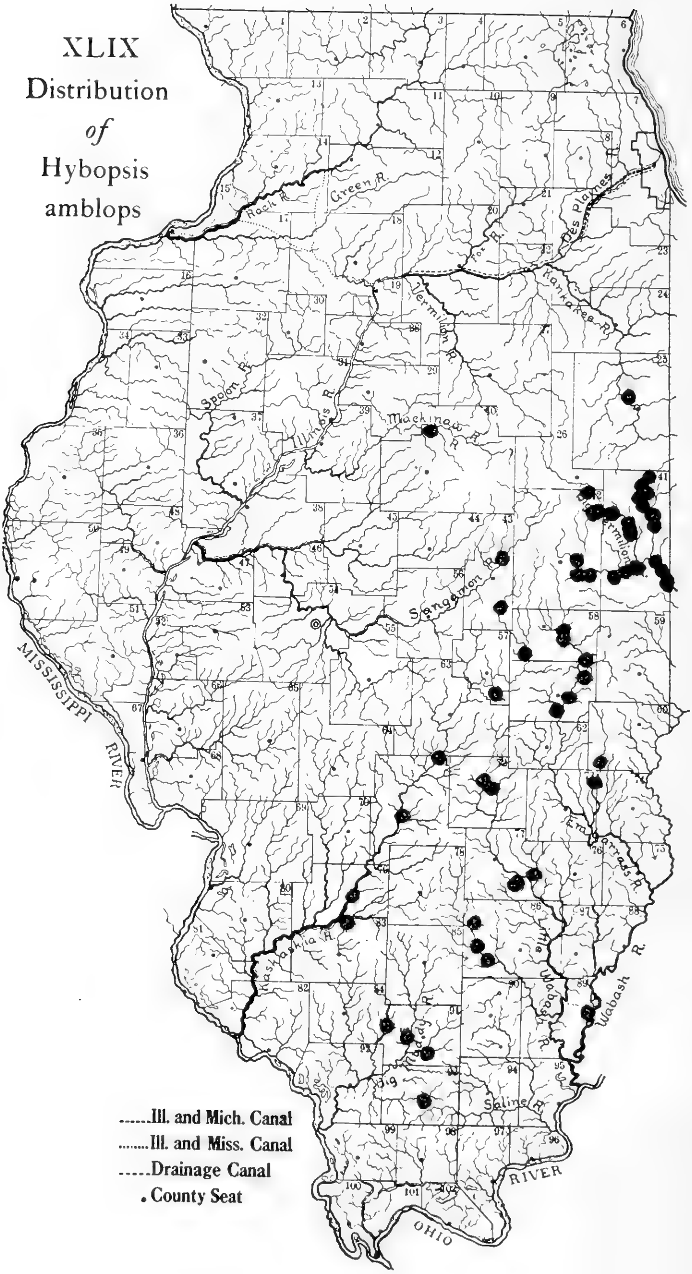


XLVII
Distribution
*of*
Phenacobius
mirabilis



XLVIII
Distribution
*of*
Hybopsis
dissimilis



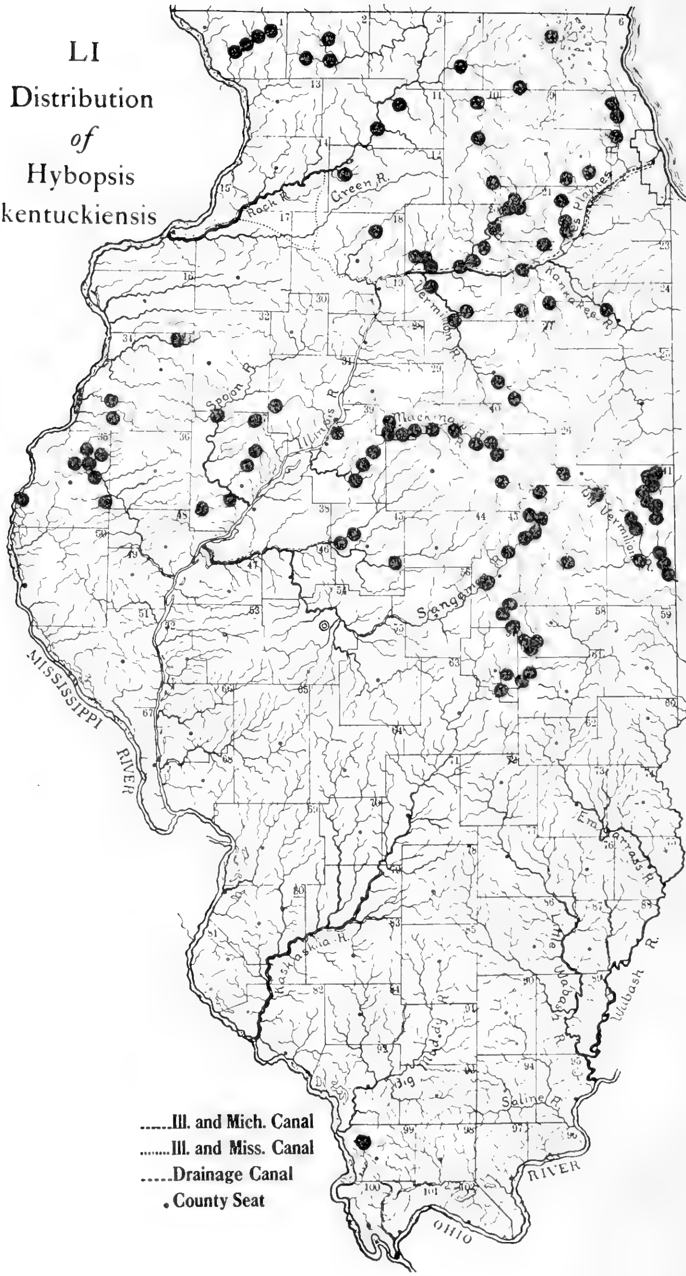



XLIX
Distribution
*of*
Hybopsis
amblops

# L
## Distribution *of* Hybopsis storerianus

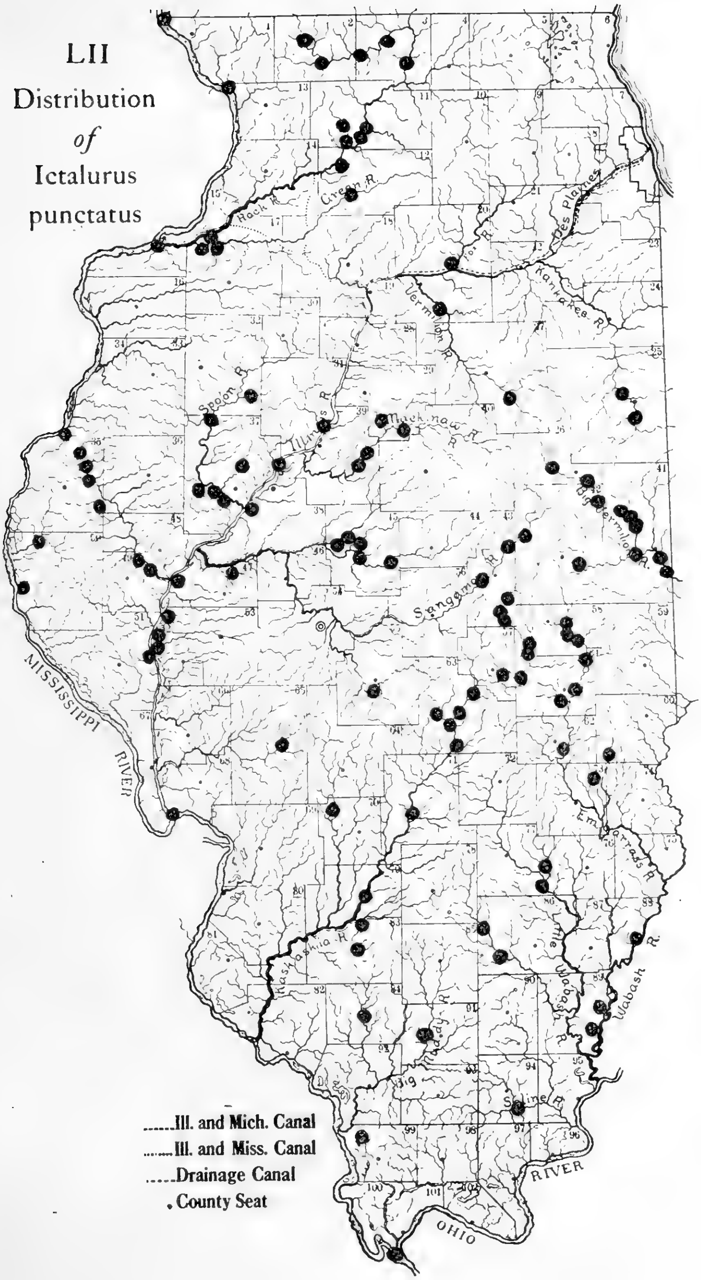

......Ill. and Mich. Canal
........Ill. and Miss. Canal
.....Drainage Canal
• County Seat

LI
Distribution
*of*
Hybopsis
kentuckiensis

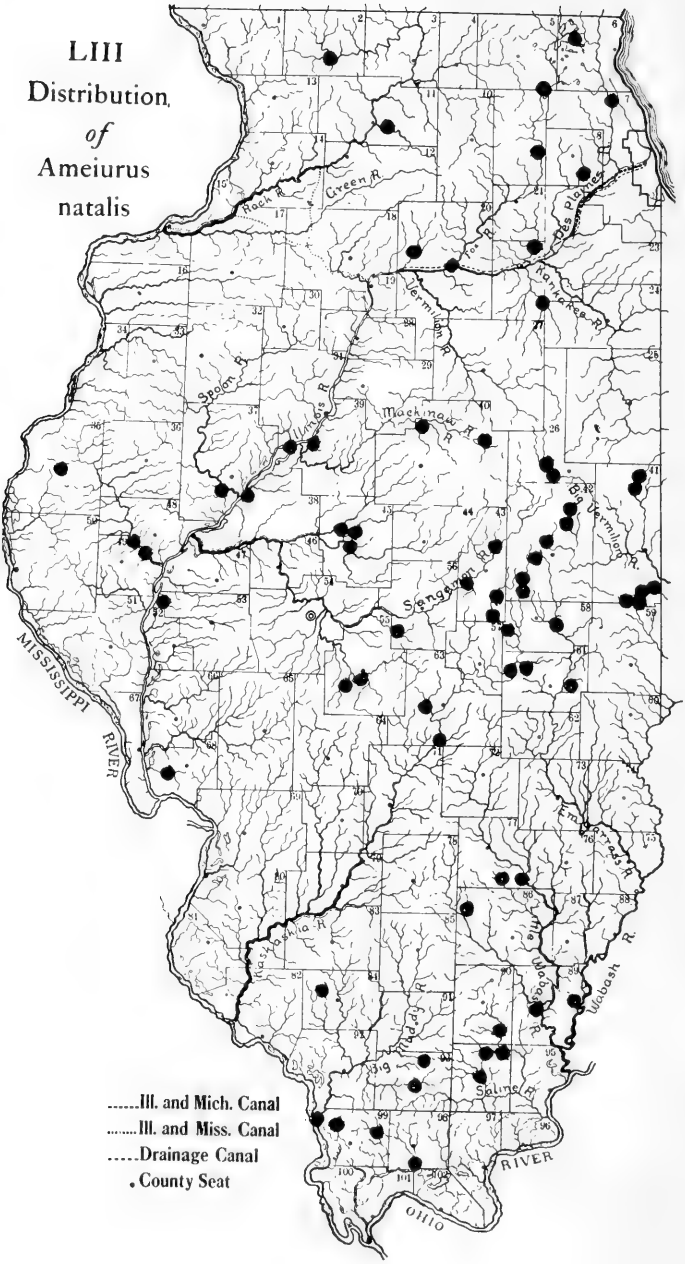


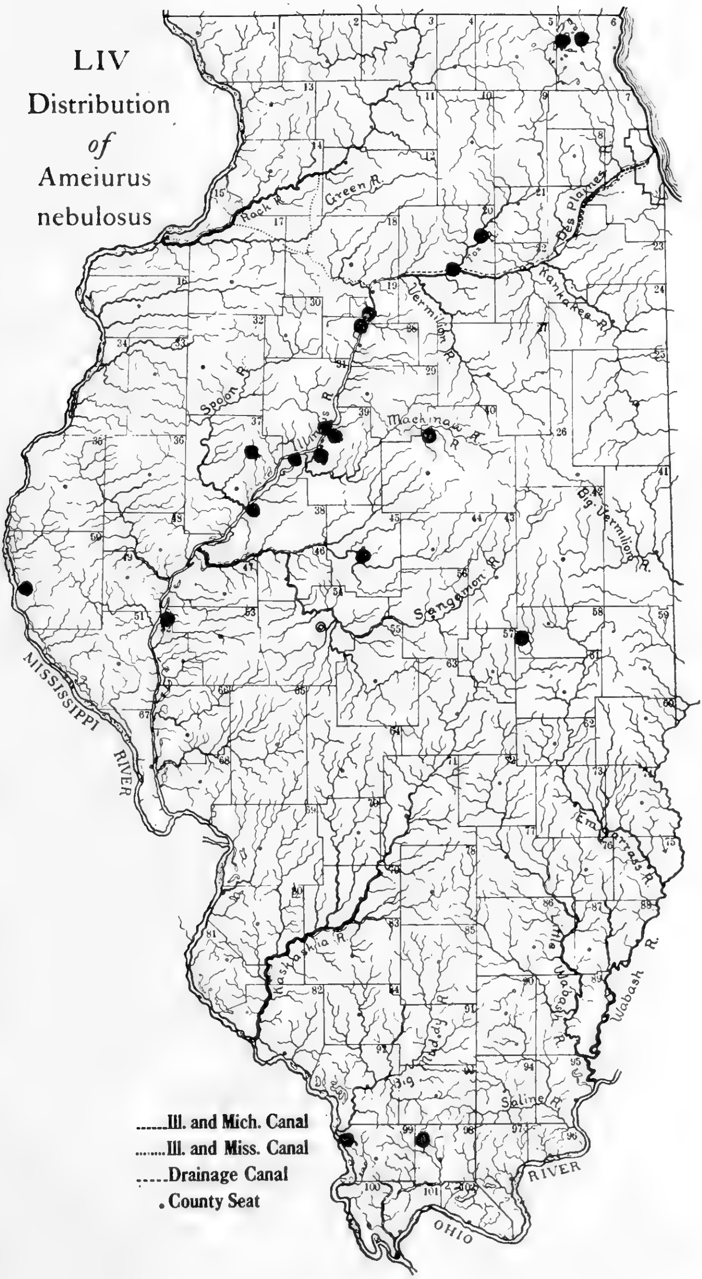

......Ill. and Mich. Canal
........Ill. and Miss. Canal
.....Drainage Canal
. County Seat

LII
Distribution
*of*
Ictalurus
punctatus



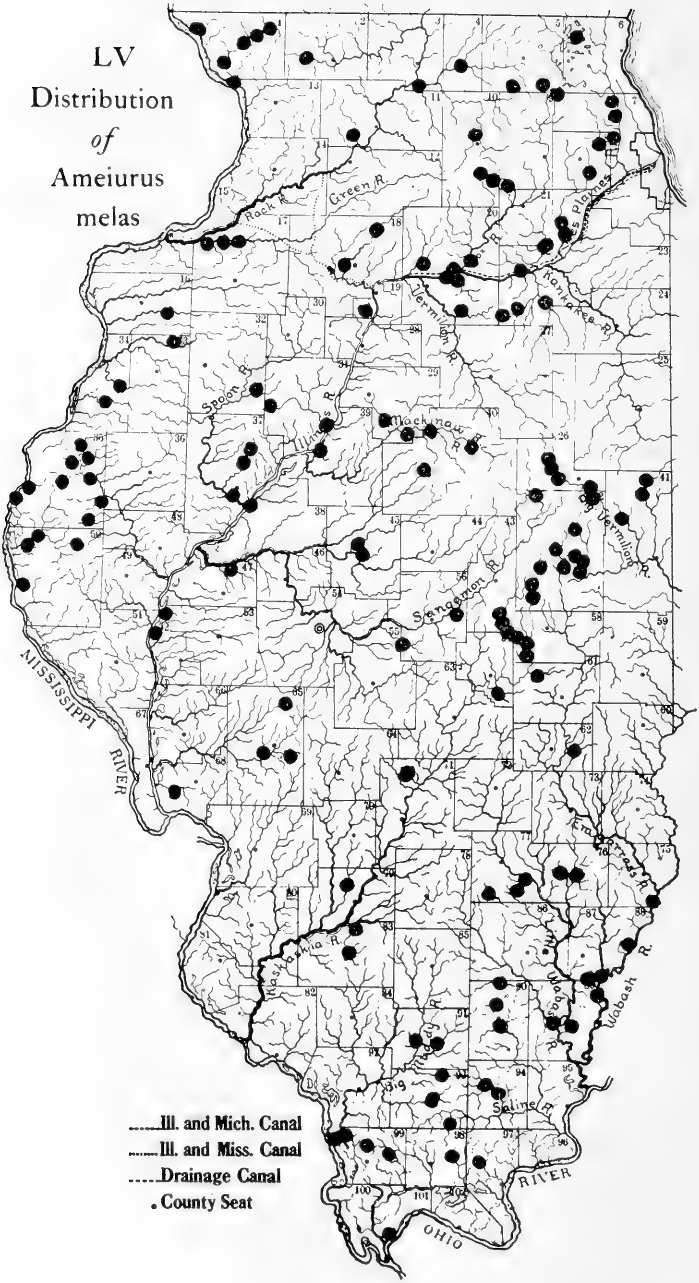
# LIII
## Distribution *of* Ameiurus natalis





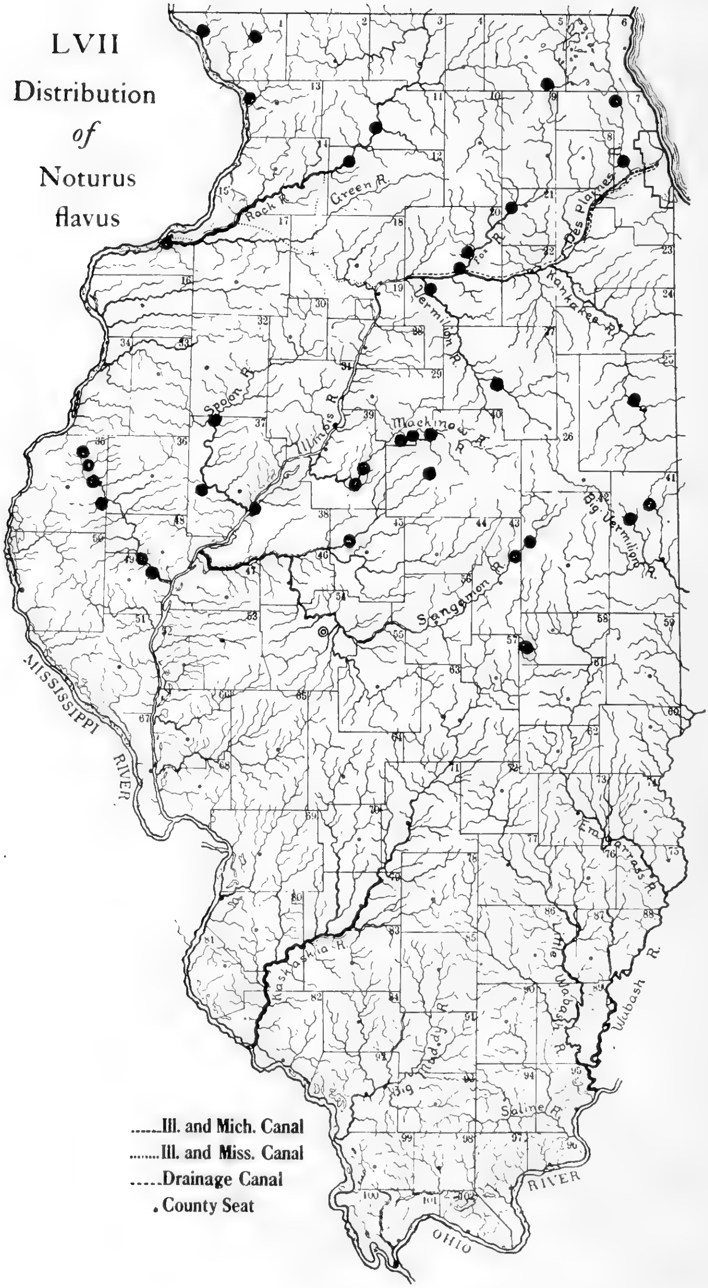

LIV
Distribution
*of*
Ameiurus
nebulosus

LV
Distribution
*of*
Ameiurus
melas

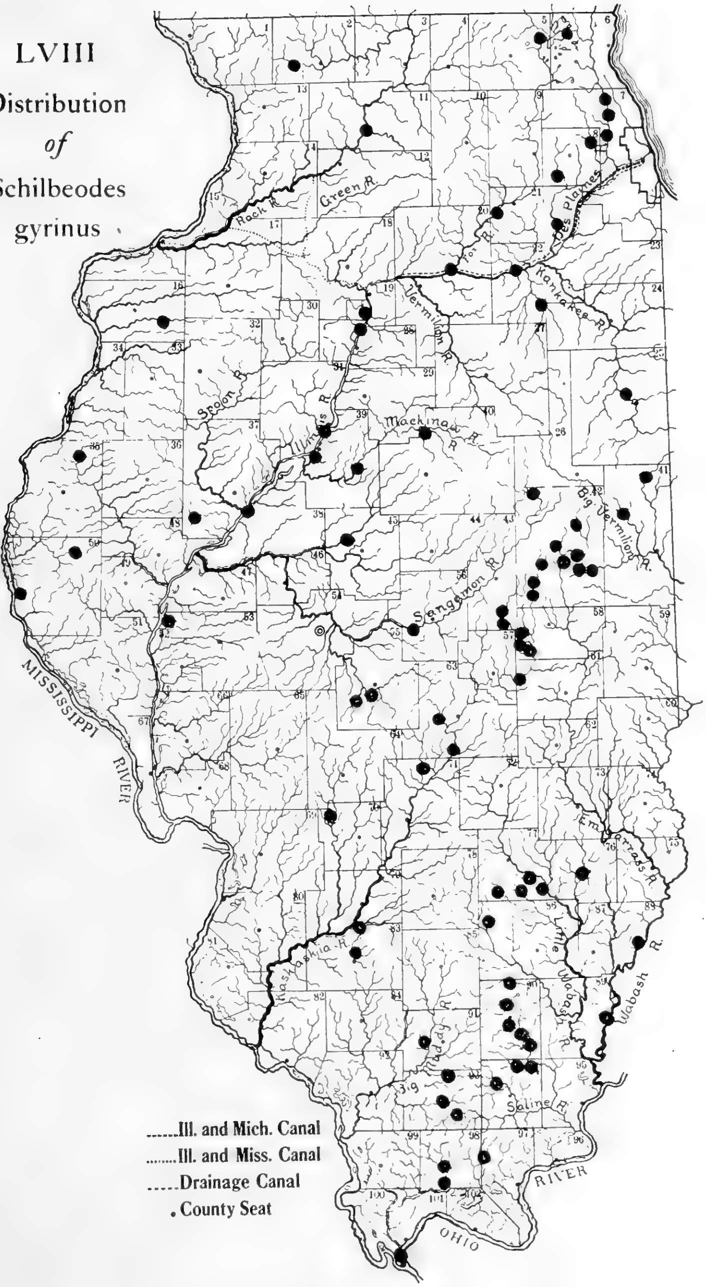


LVI
Distribution
*of*
Leptops
olivaris

LVII
Distribution
*of*
Noturus
flavus

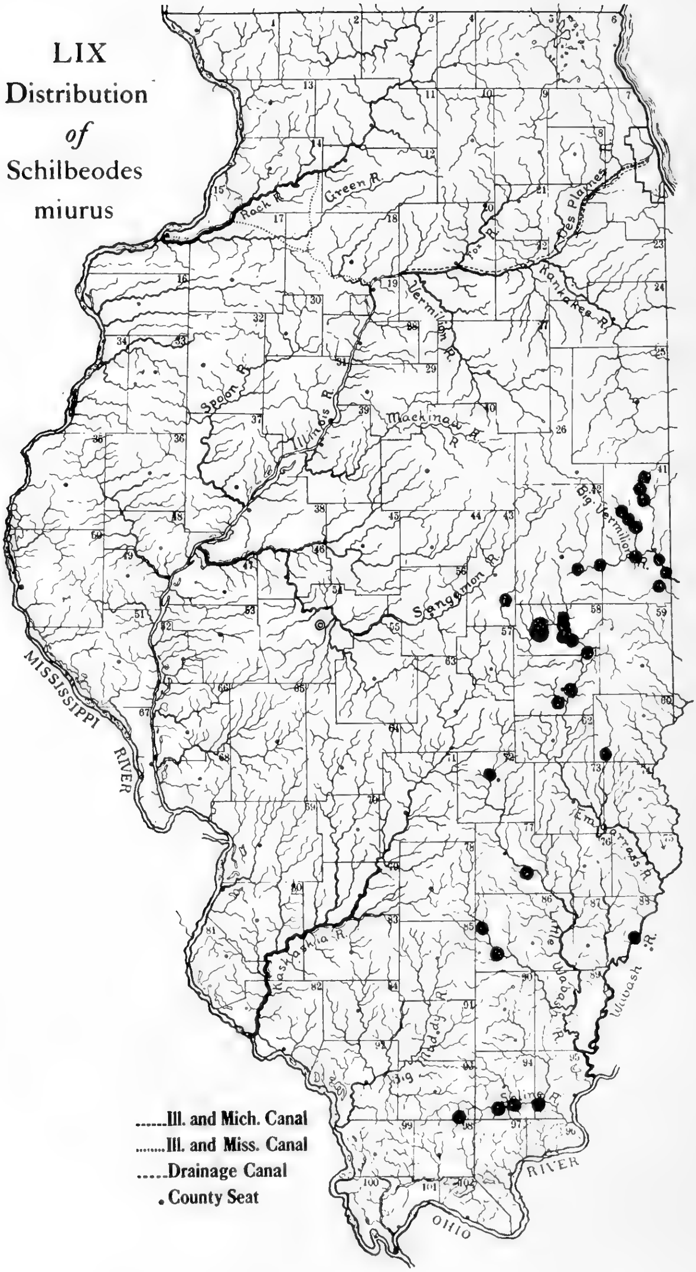


# LVIII
Distribution
*of*
Schilbeodes
gyrinus



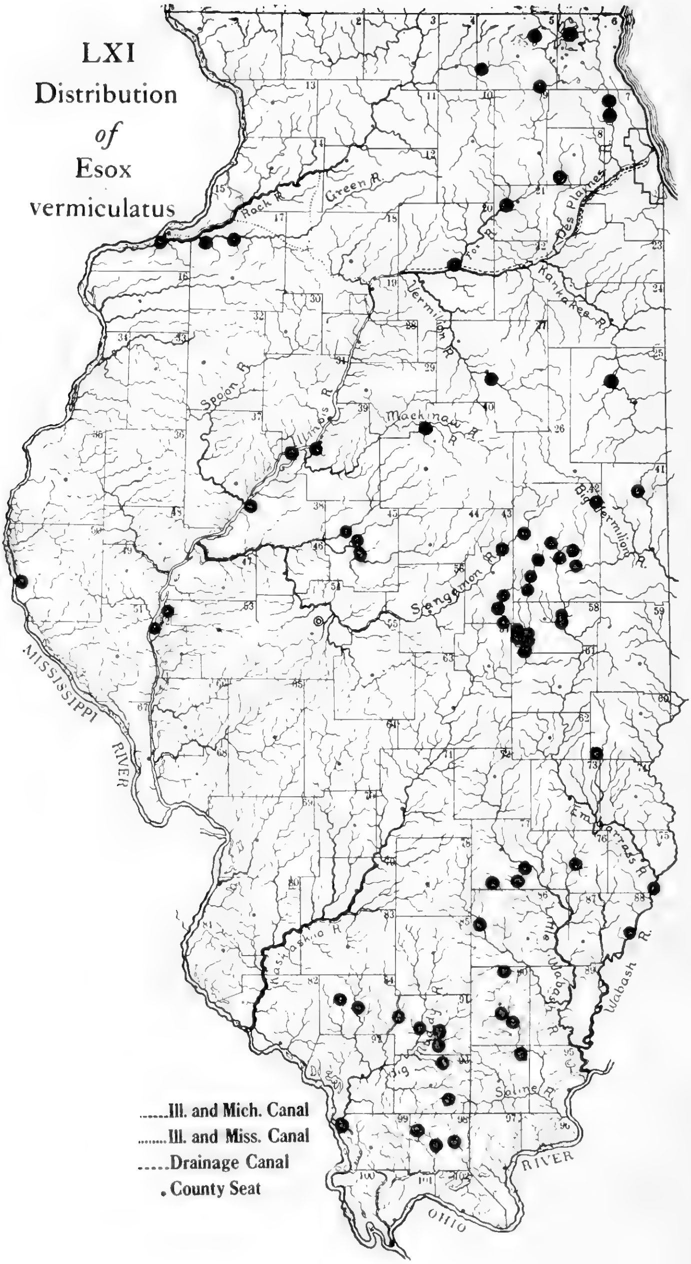

......Ill. and Mich. Canal
........Ill. and Miss. Canal
.....Drainage Canal
. County Seat

LIX
Distribution
*of*
Schilbeodes
miurus



LX
Distribution
*of*
Umbra
limi

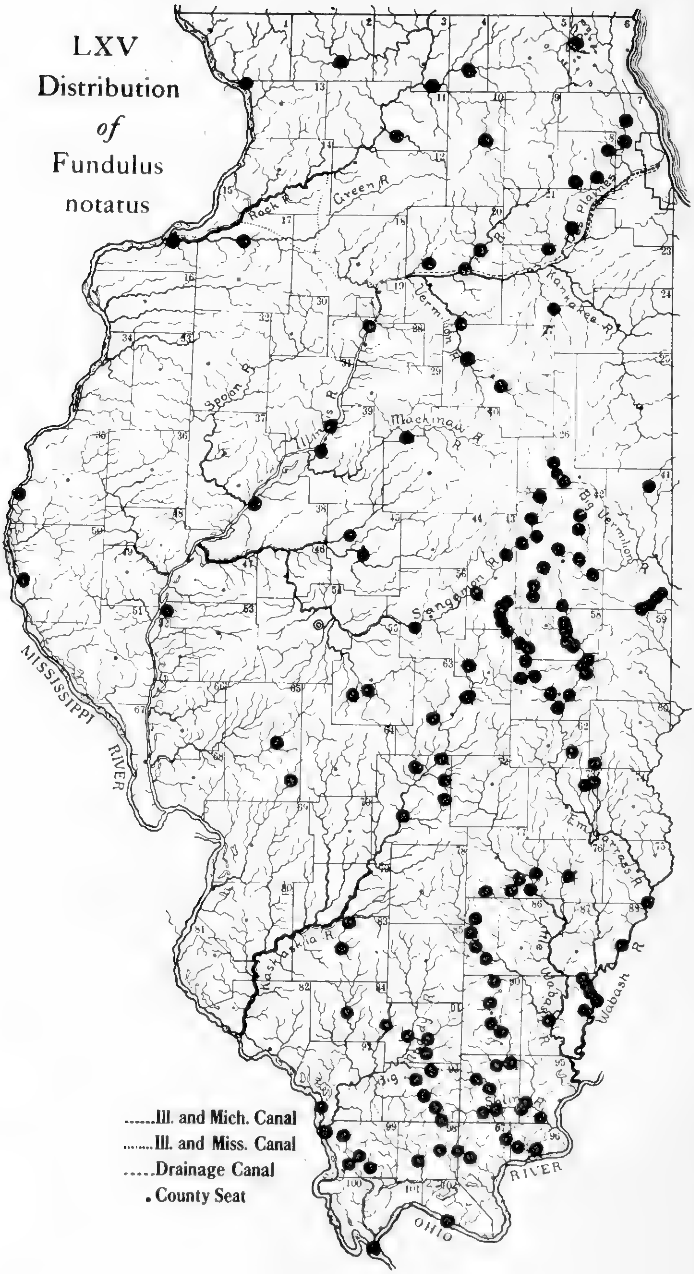
# LXI
## Distribution *of* Esox vermiculatus



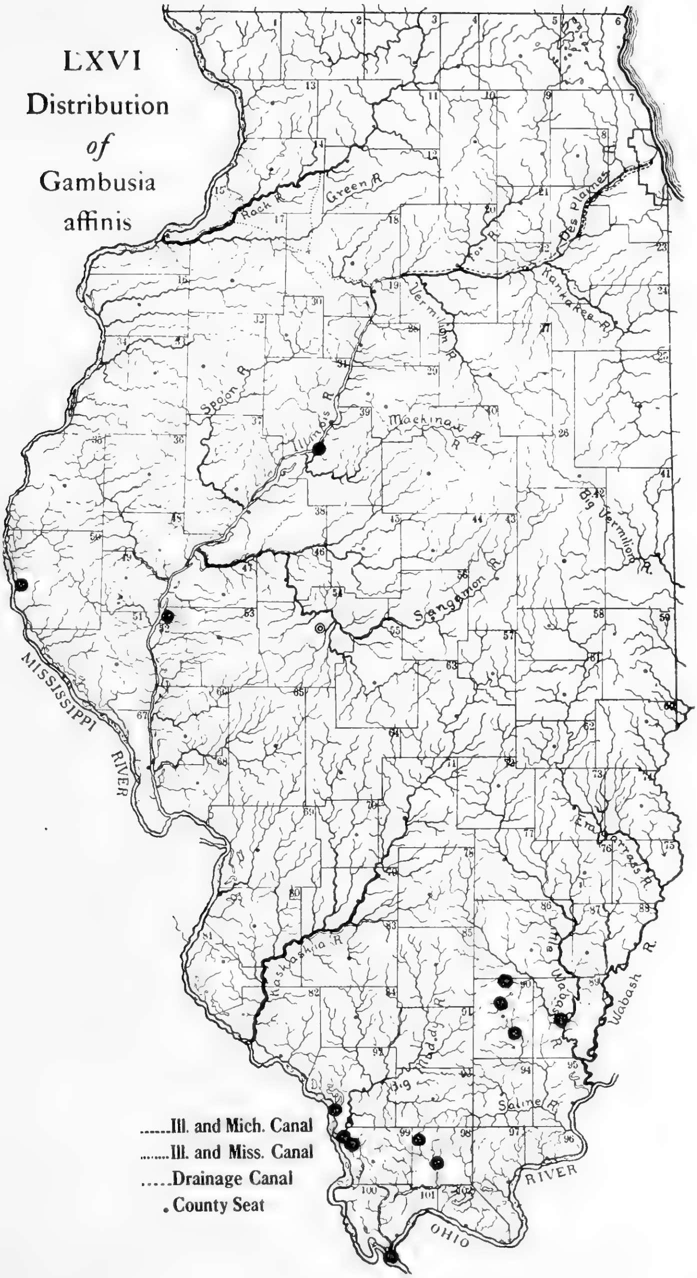

LXII
Distribution
of
Esox
lucius
Rock R.
Green R.
Des Plaines
Kankakee R.
Vermilion R.
Spoon R.
Illinois R.
Mackinaw R.
Big Vermilion R.
Sangamon R.
MISSISSIPPI
RIVER
Kaskaskia R.
Embarrass R.
Little Wabash R.
Wabash R.
Big Muddy R.
Saline R.
RIVER
OHIO
......Ill. and Mich. Canal
......Ill. and Miss. Canal
.....Drainage Canal
. County Seat


LXIII
Distribution
of
Fundulus
diaphanus
menona
Rock R.
Green R.
Des Plaines
Fox R.
Kankakee R.
Vermilion R.
Spoon R.
Illinois R.
Mackinaw R.
Big Vermilion R.
Sangamon R.
MISSISSIPPI
RIVER
Embarrass R.
Little Wabash R.
Wabash R.
Kaskaskia R.
Big Muddy R.
Saline R.
OHIO
RIVER
......Ill. and Mich. Canal
......Ill. and Miss. Canal
.....Drainage Canal
. County Seat

LXIV
Distribution
*of*
Fundulus
dispar

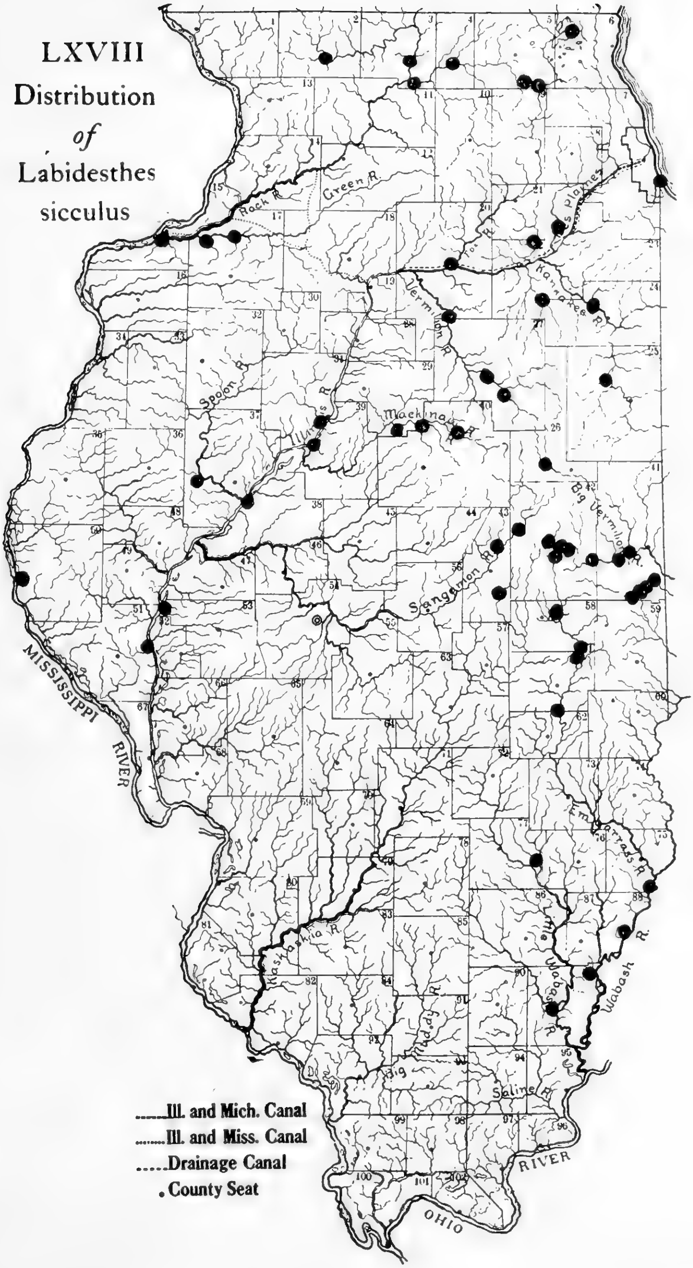


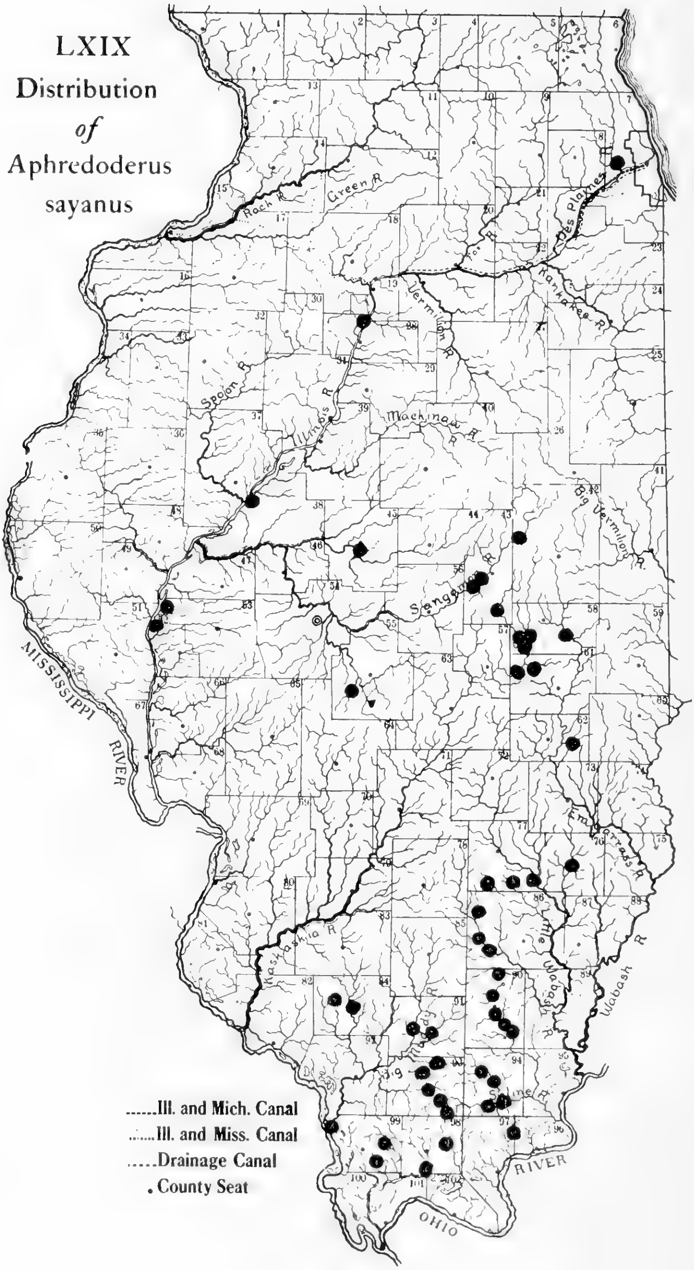

LXV
Distribution
*of*
Fundulus
notatus


LXVI
Distribution
of
Gambusia
affinis
Rock R.
Green R.
Des Plaines R.
Fox R.
Kankakee R.
Vermilion R.
Spoon R.
Illinois R.
Mackinaw R.
Big Vermilion R.
Sangamon R.
Kaskaskia R.
Embarrass R.
Little Wabash R.
Wabash R.
Big Muddy R.
Saline R.
MISSISSIPPI RIVER
OHIO RIVER
......Ill. and Mich. Canal
........Ill. and Miss. Canal
.....Drainage Canal
. County Seat

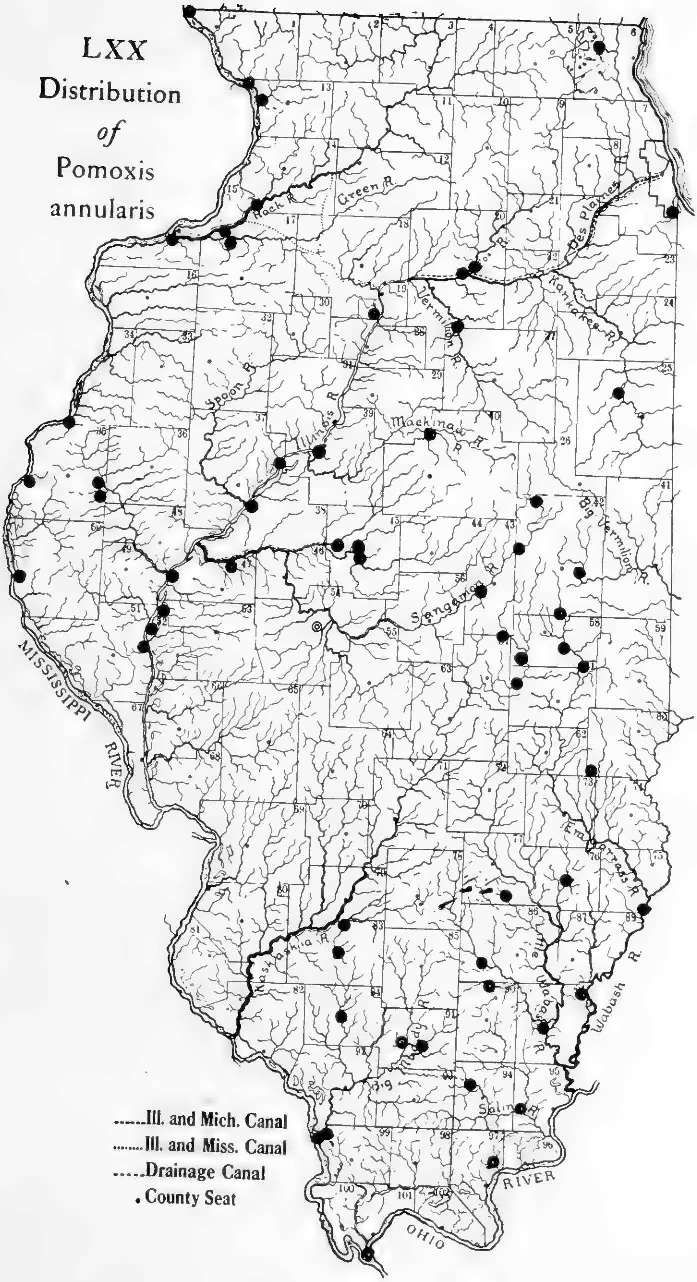

LXVII
Distribution
*of*
Percopsis
guttatus

## LXVIII
## Distribution *of* Labidesthes sicculus

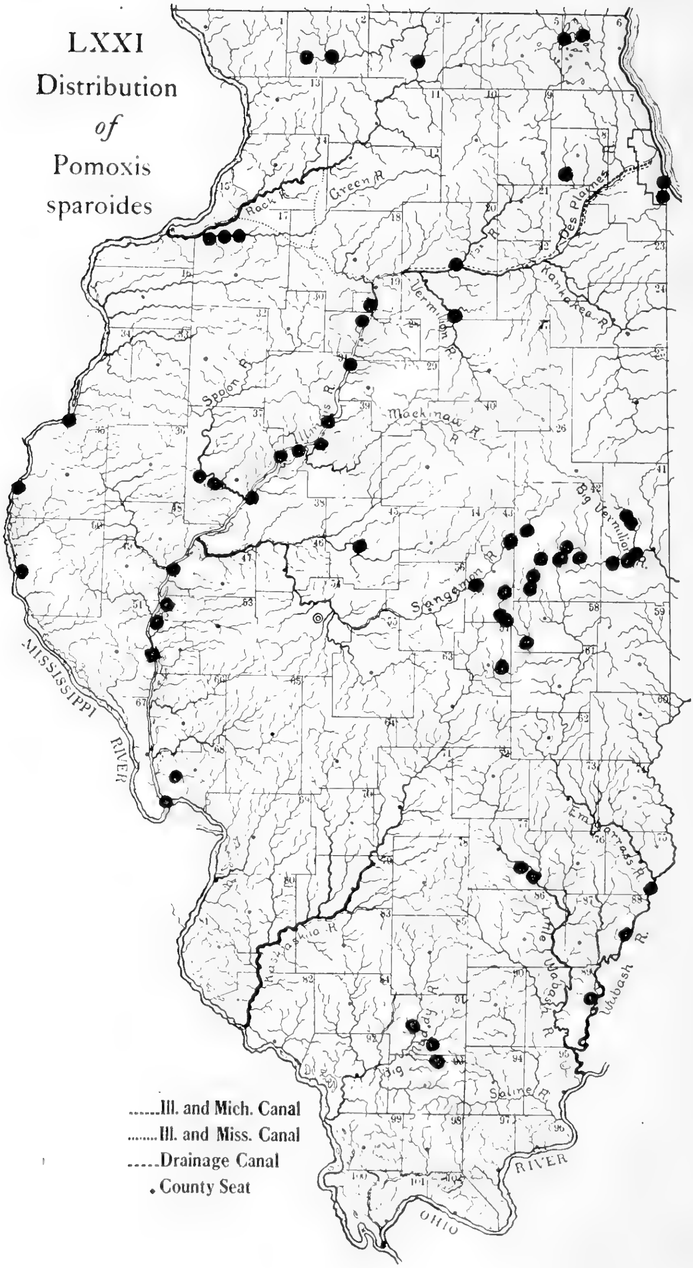





LXIX
Distribution
*of*
Aphredoderus
sayanus

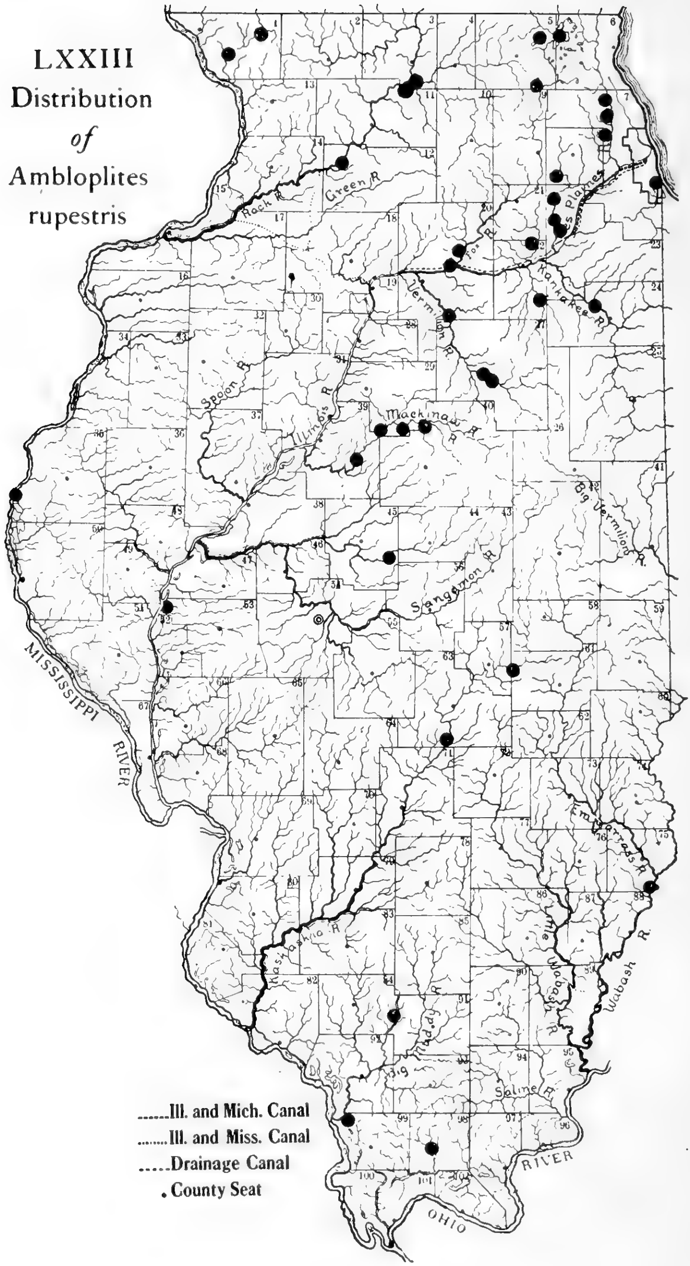

LXX
Distribution
of
Pomoxis
annularis
Rock R.
Green R.
Des Plaines
Kankakee R.
Vermilion R.
Spoon R.
Illinois R.
Mackinaw R.
Big Vermilion R.
Sangamon R.
MISSISSIPPI
RIVER
Embarrass R.
Kaskaskia R.
Little Wabash R.
Wabash R.
Saline R.
OHIO
RIVER
......Ill. and Mich. Canal
........Ill. and Miss. Canal
.....Drainage Canal
• County Seat

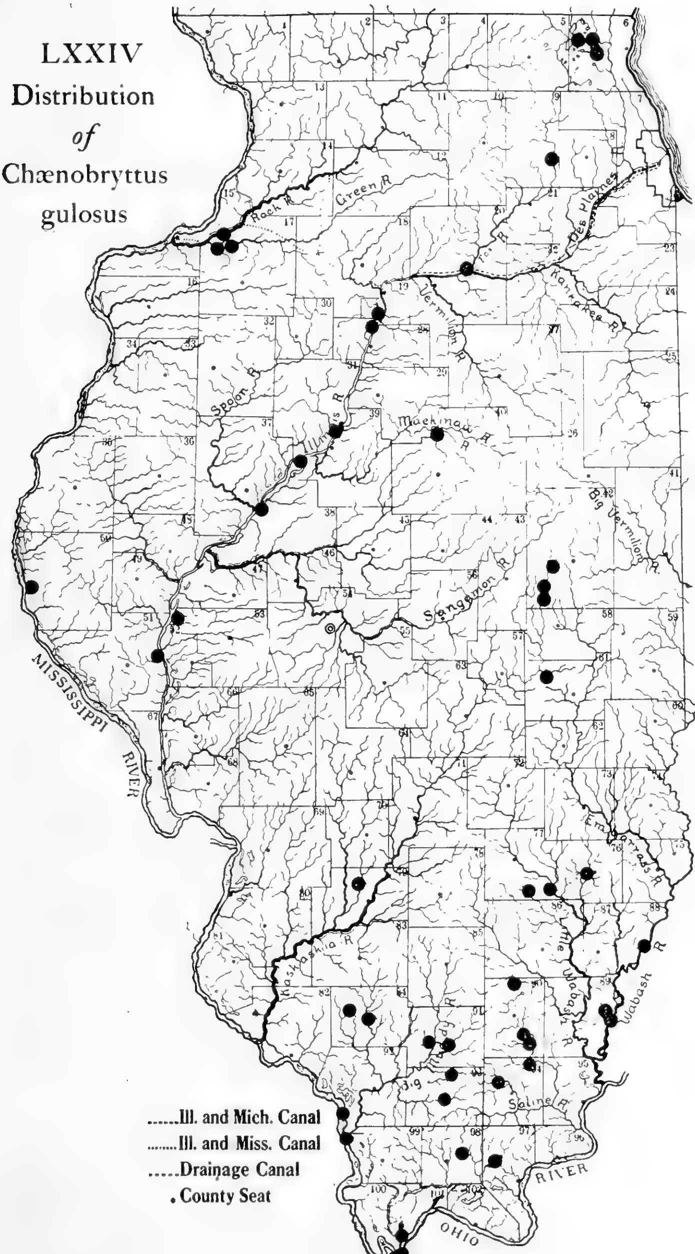
LXXI
Distribution
*of*
Pomoxis
sparoides



LXXII
Distribution
*of*
Centrarchus
macropterus

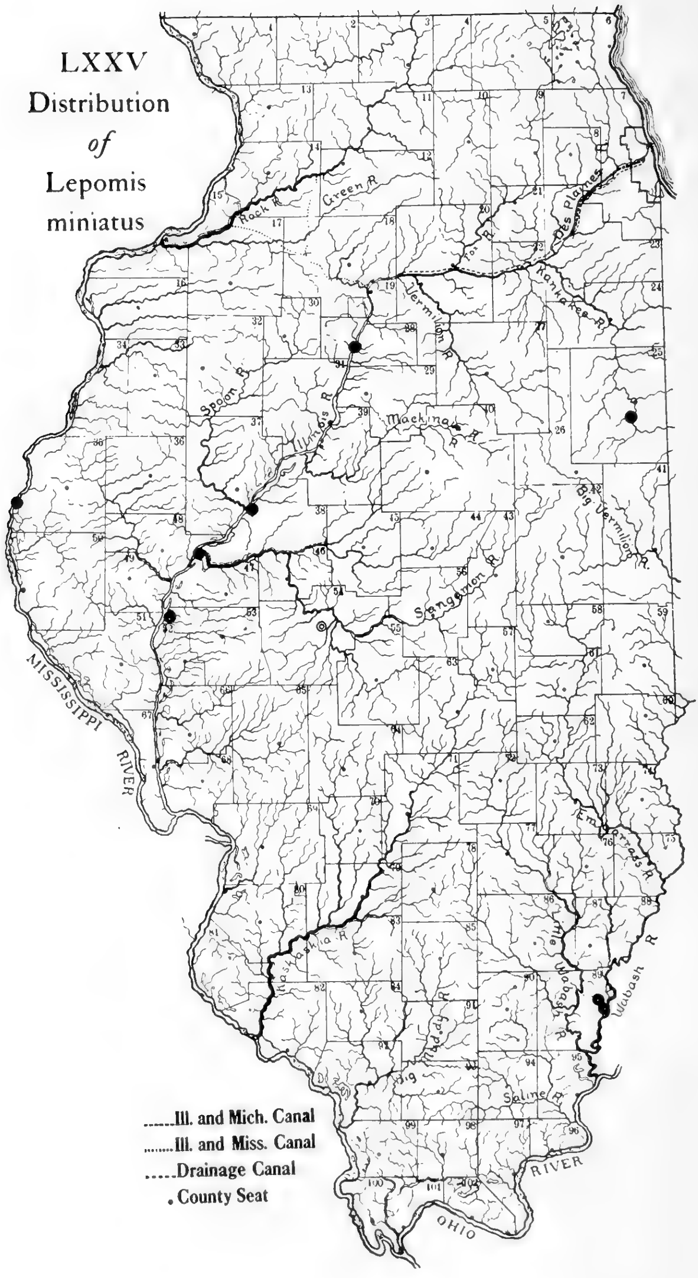
**LXXIII**
**Distribution**
*of*
**Ambloplites rupestris**



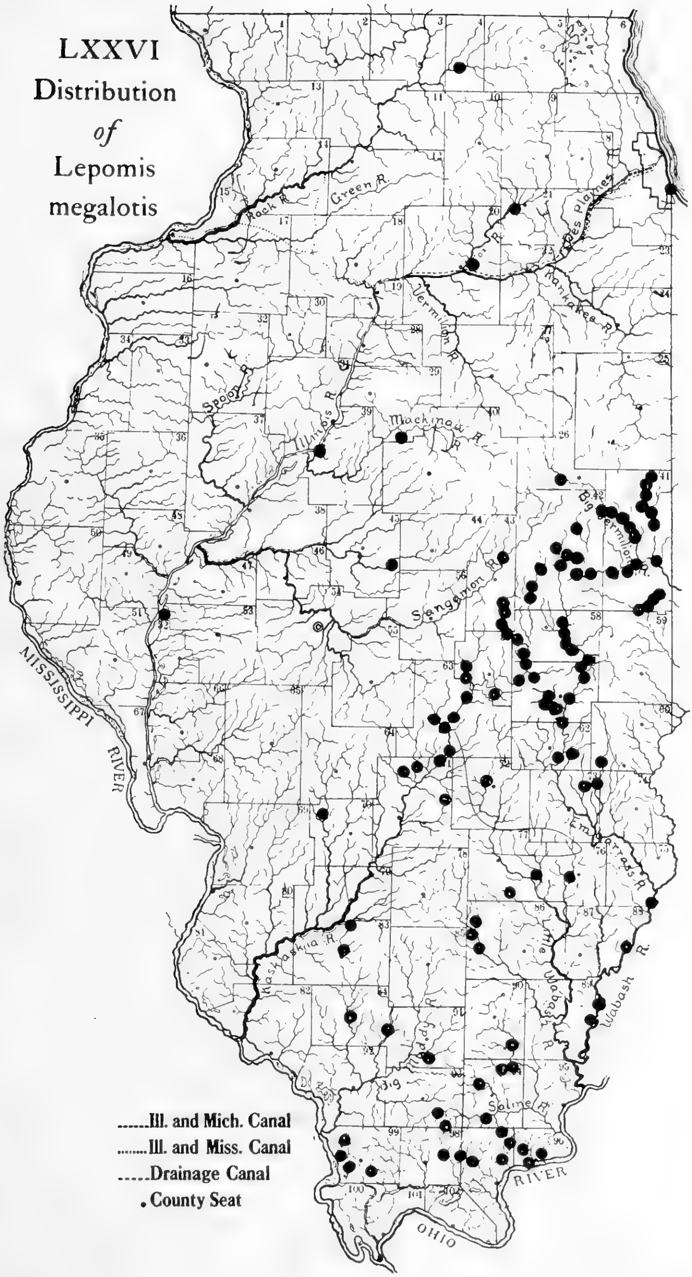



LXXIV
Distribution
*of*
Chænobryttus
gulosus

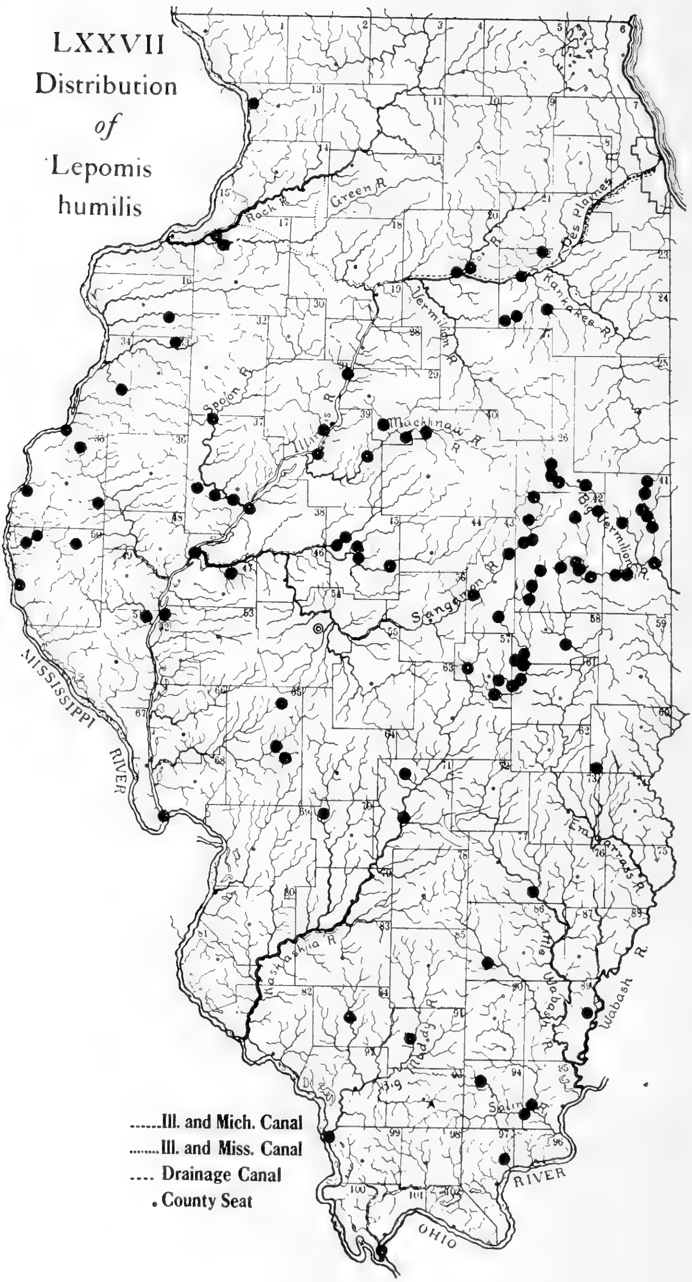
# LXXV
## Distribution *of* Lepomis miniatus



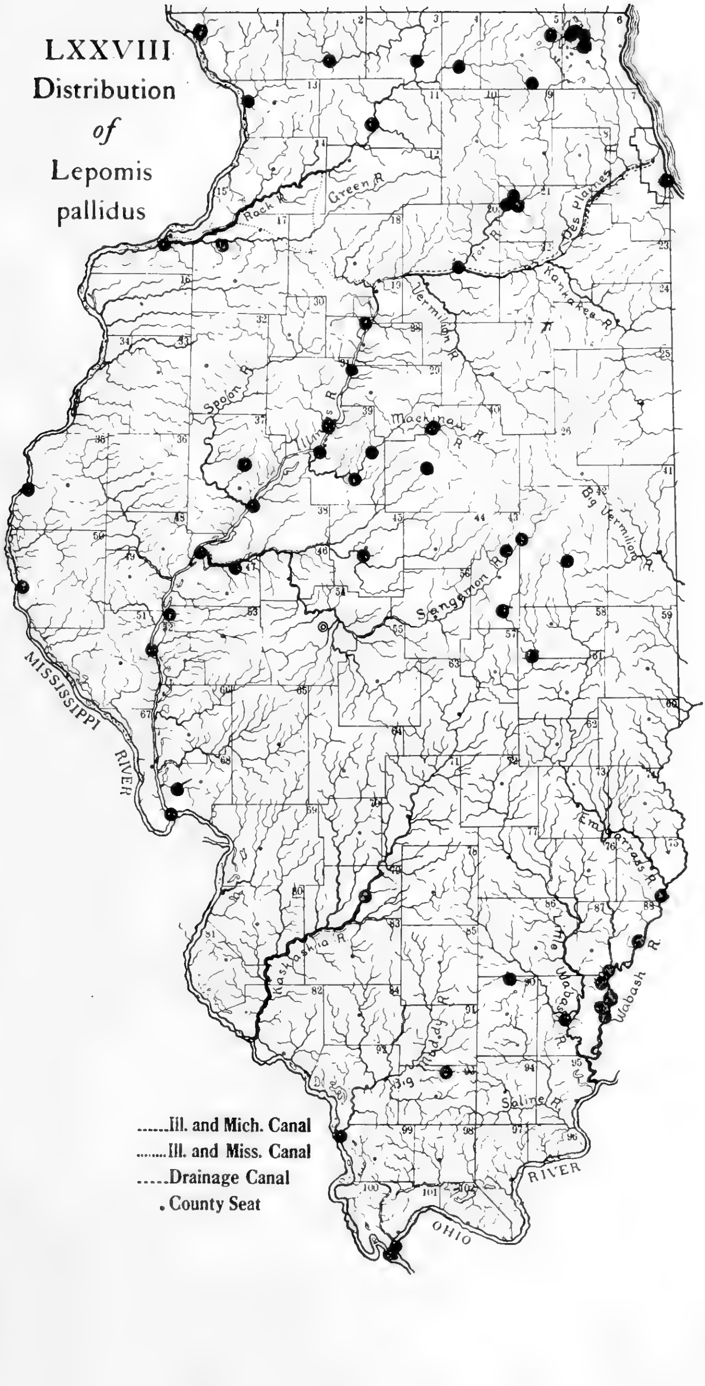
**LXXVI**
**Distribution**
*of*
**Lepomis megalotis**



## LXXVII
Distribution
*of*
Lepomis humilis

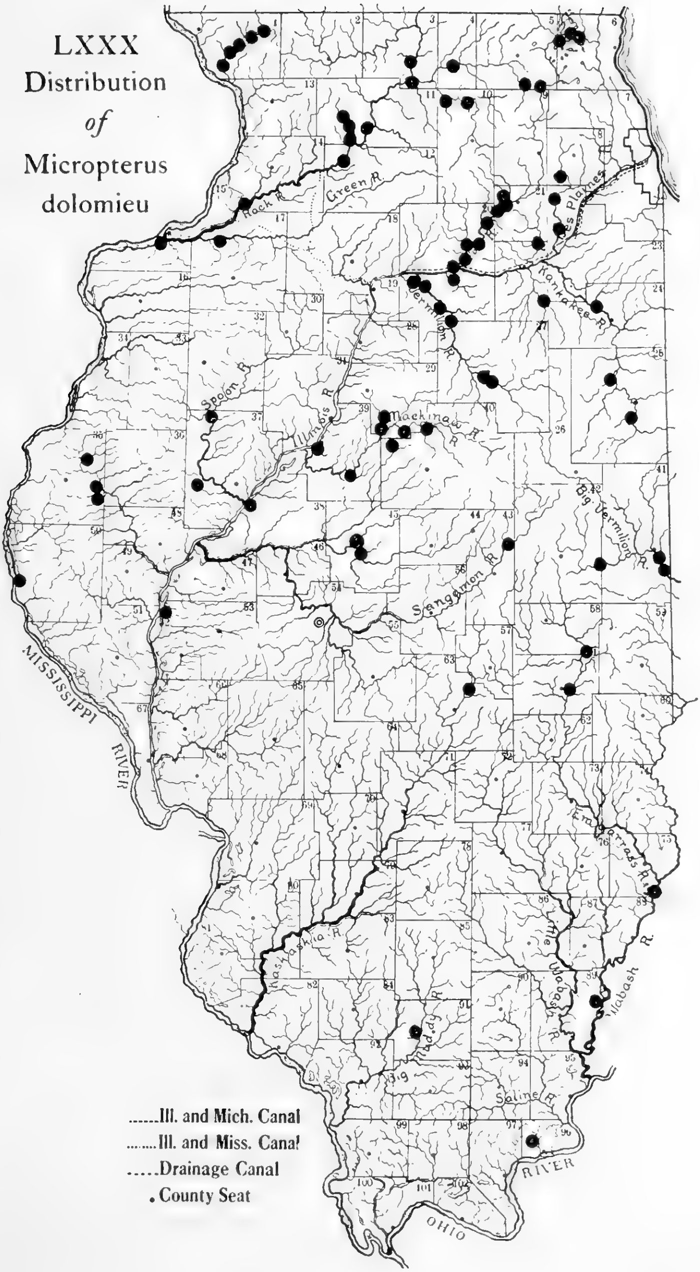


# LXXVIII Distribution *of* Lepomis pallidus



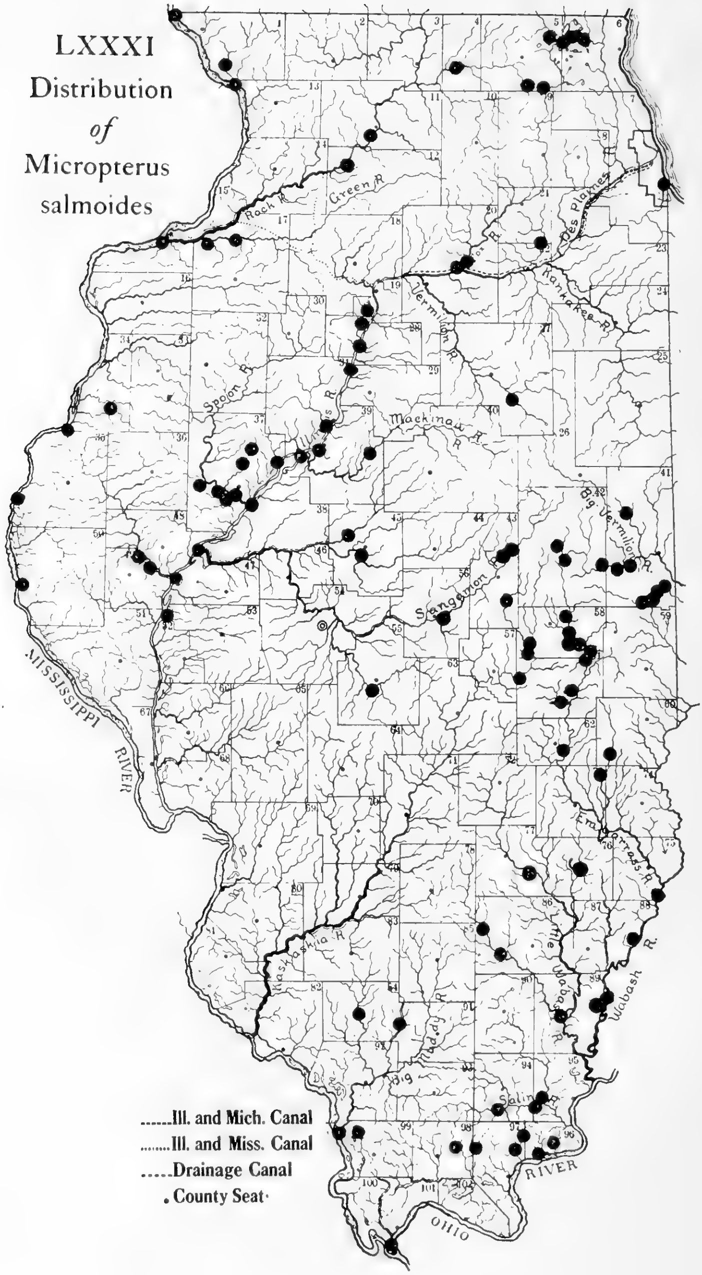

......Ill. and Mich. Canal
........Ill. and Miss. Canal
.....Drainage Canal
. County Seat


LXXIX
Distribution
of
Eupomotis
gibbosus
Rock R.
Green R.
Des Plaines
Kankakee R.
Vermilion R.
Spoon R.
Illinois R.
Mackinaw R.
Big Vermilion R.
Sangamon R.
MISSISSIPPI
RIVER
Embarrass R.
Little Wabash R.
Wabash R.
Kaskaskia R.
Big Muddy R.
Saline R.
OHIO
RIVER
......Ill. and Mich. Canal
........Ill. and Miss. Canal
.....Drainage Canal
. County Seat

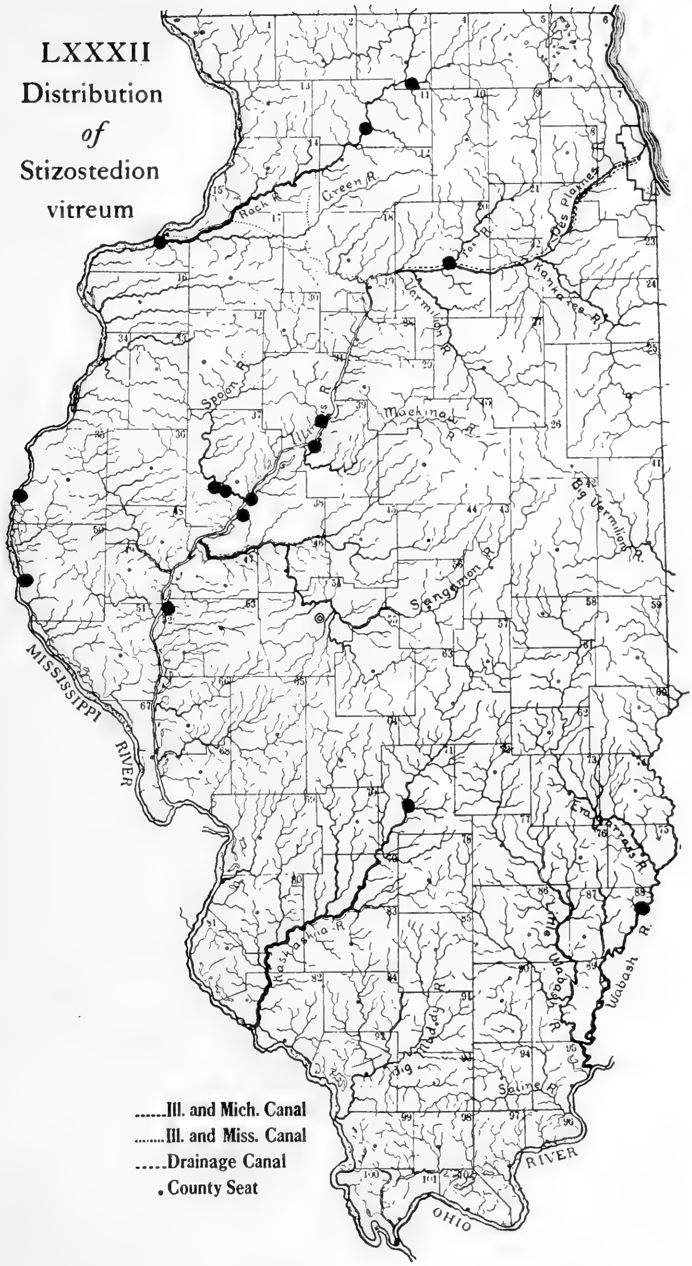



LXXX
Distribution
*of*
Micropterus
dolomieu

LXXXI
Distribution
*of*
Micropterus
salmoides



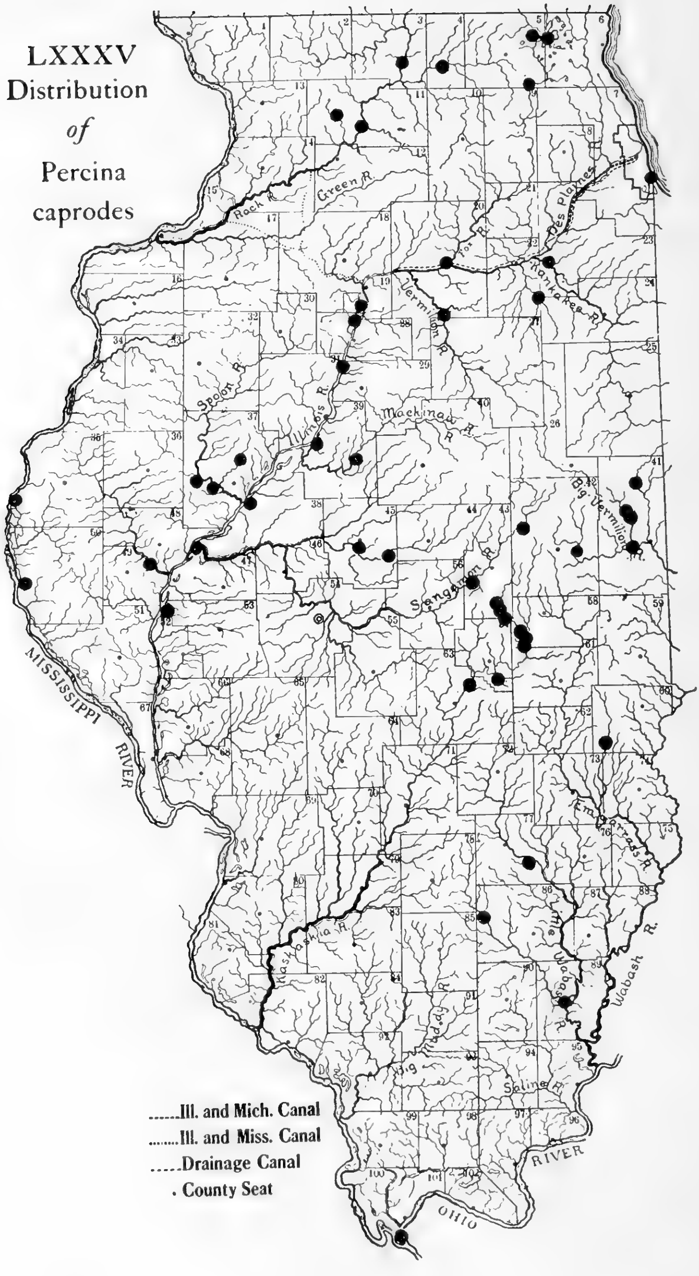
# LXXXII
## Distribution *of* Stizostedion vitreum



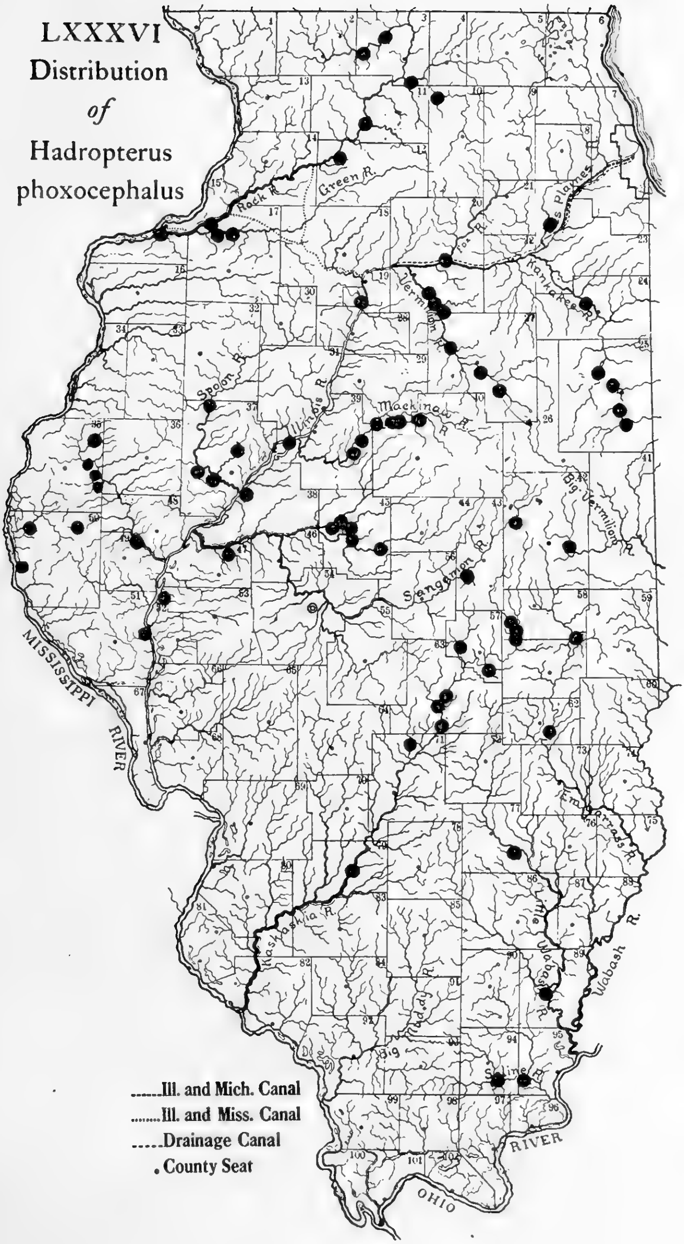
LXXXIII
Distribution
*of*
Stizostedion
canadense
griseum

# LXXXIV
Distribution
*of*
Perca
flavescens

LXXXV
Distribution
*of*
Percina
caprodes

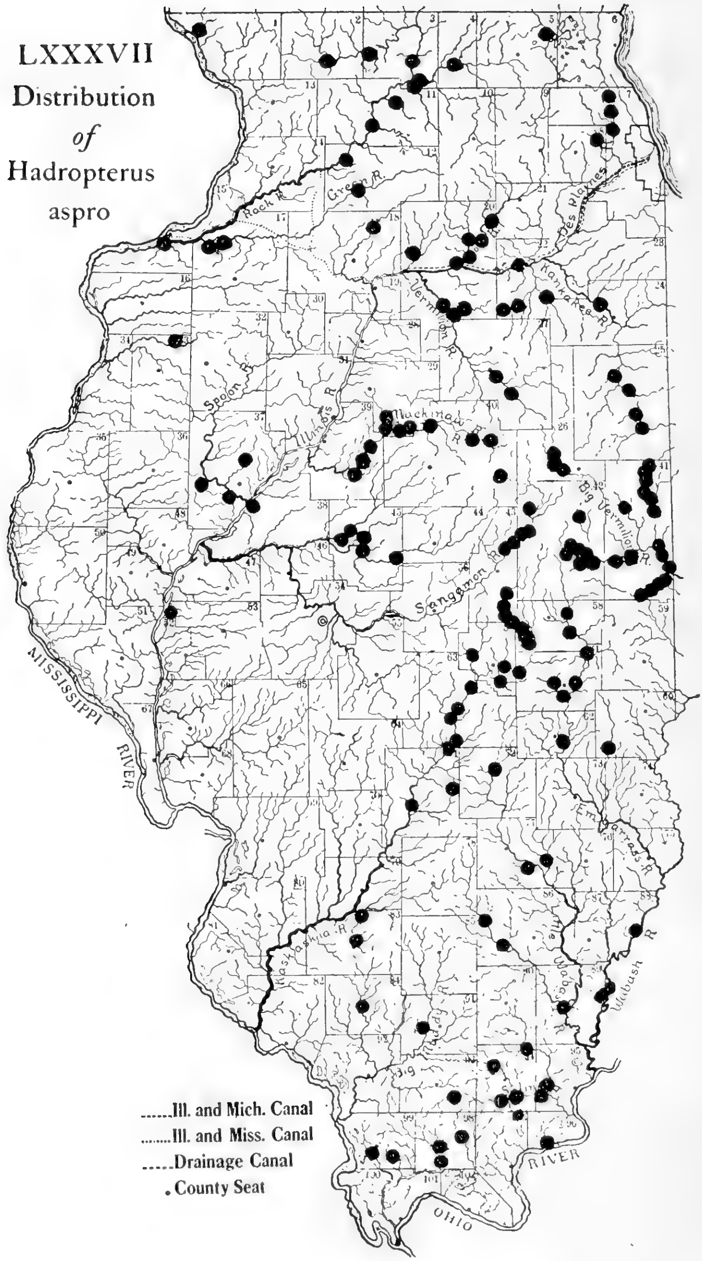



......Ill. and Mich. Canal
........Ill. and Miss. Canal
.....Drainage Canal
. County Seat



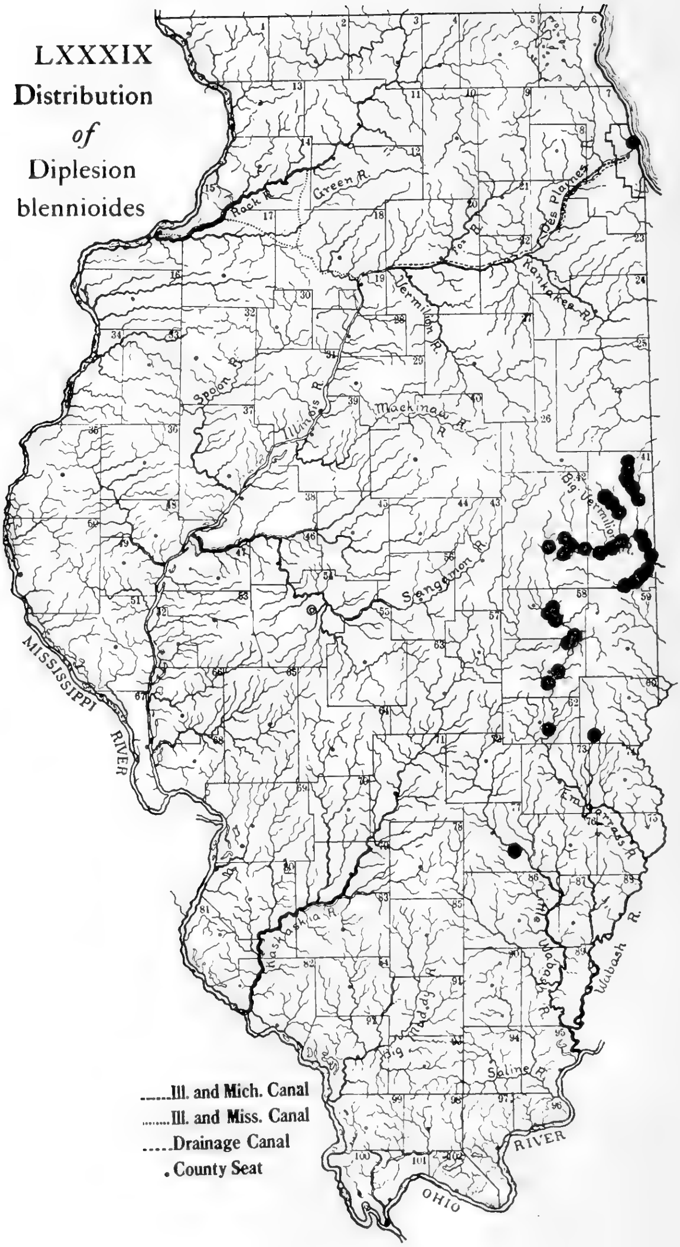

LXXXVI
Distribution
*of*
Hadropterus
phoxocephalus

LXXXVII
Distribution
*of*
Hadropterus
aspro

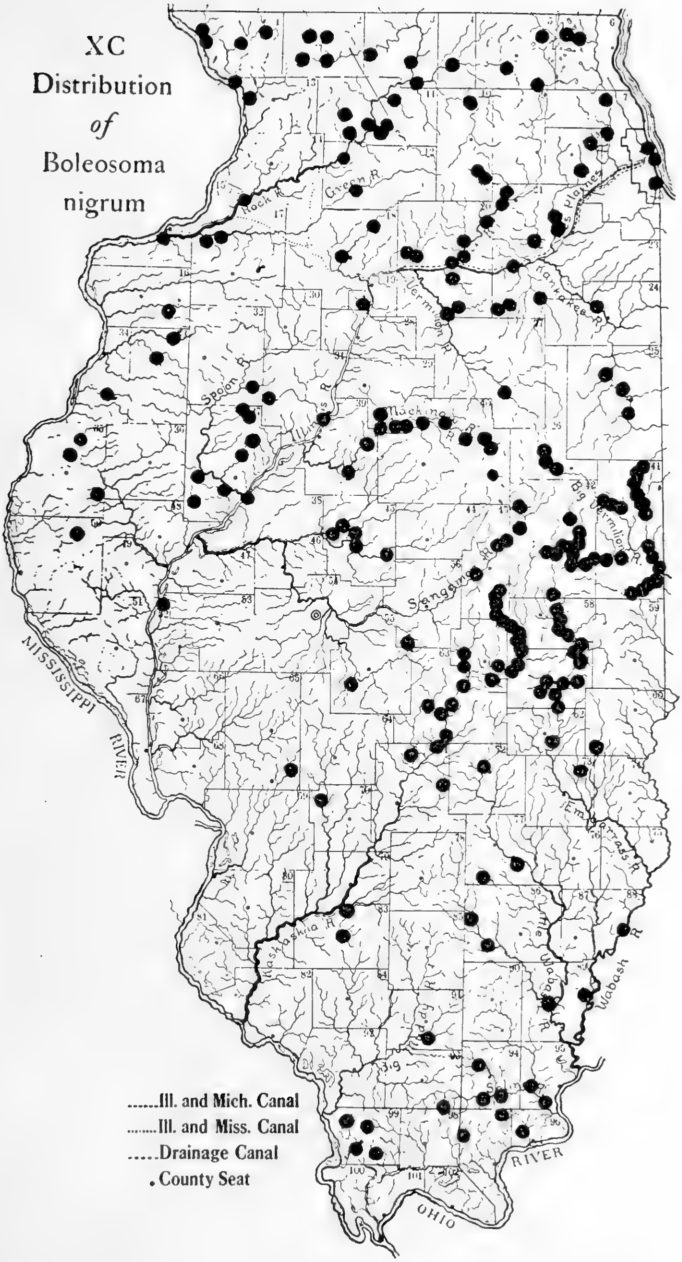


LXXXVIII
Distribution
*of*
Cottogaster
shumardi

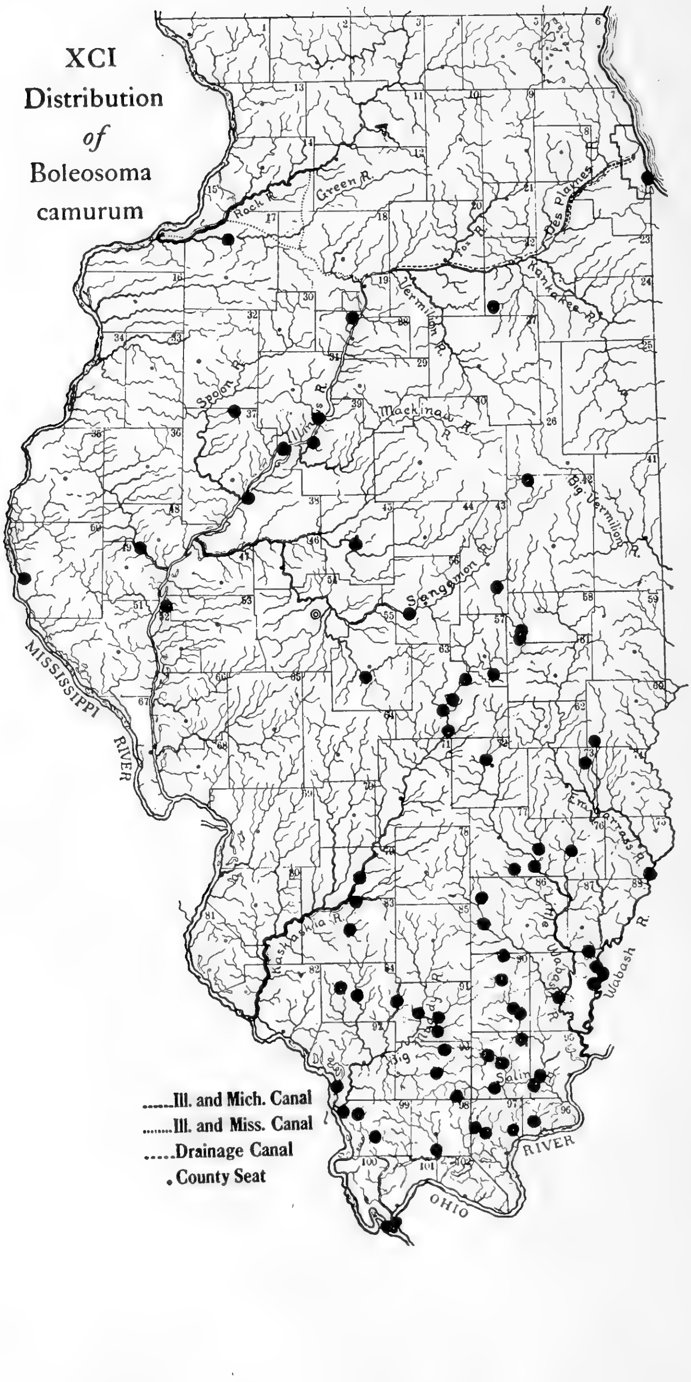
LXXXIX
Distribution
*of*
Diplesion
blennioides



XC
Distribution
*of*
Boleosoma
nigrum

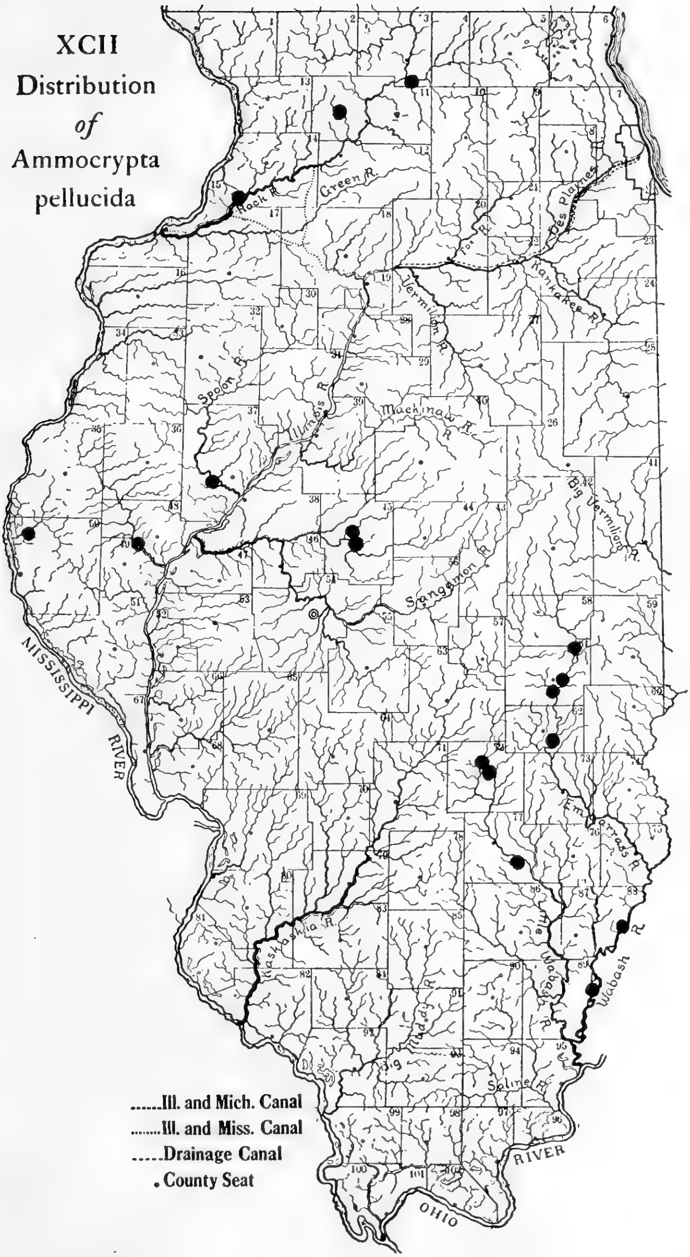


XCI
Distribution
*of*
Boleosoma
camurum



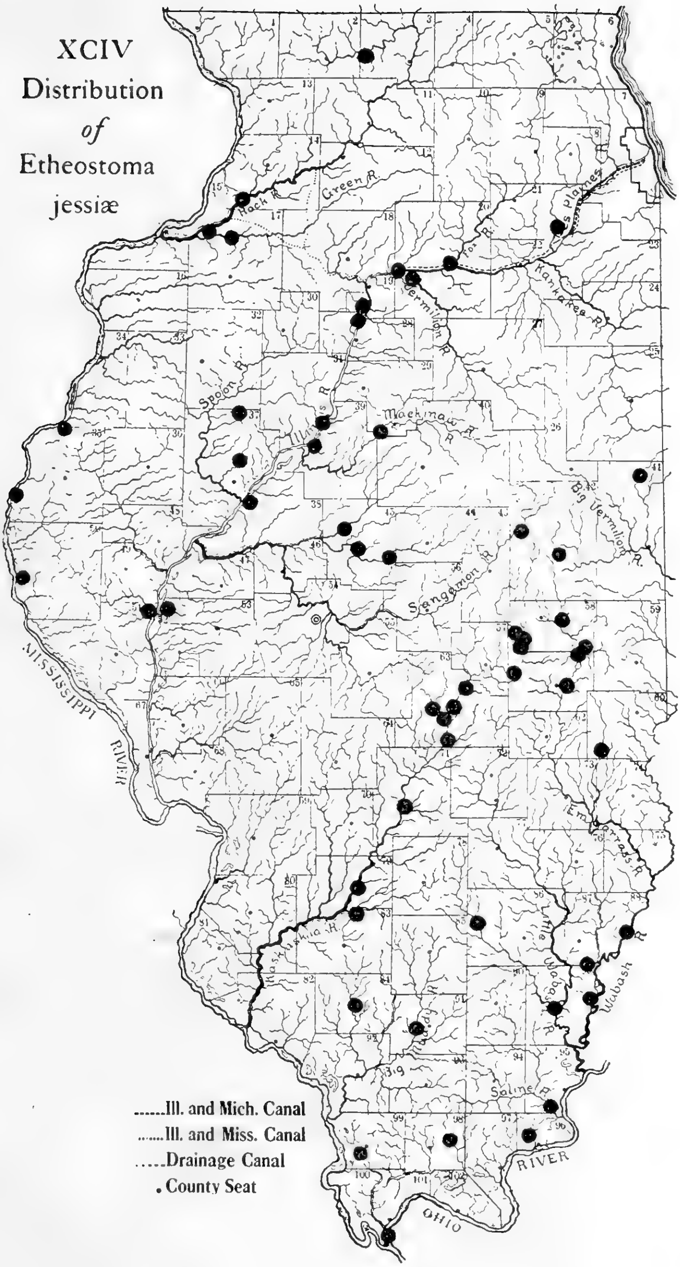

......Ill. and Mich. Canal
.........Ill. and Miss. Canal
.....Drainage Canal
. County Seat

XCII
Distribution
*of*
Ammocrypta
pellucida

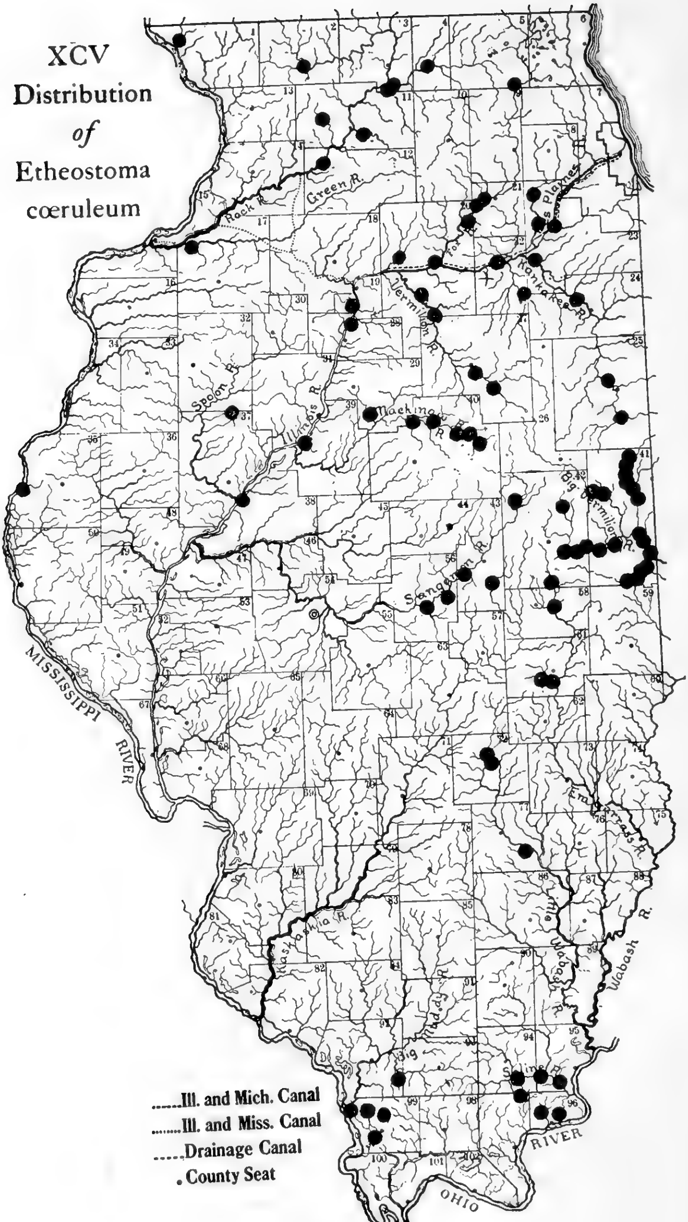


# XCIII
Distribution *of* Etheostoma zonale

XCIV
Distribution
*of*
Etheostoma
jessiæ



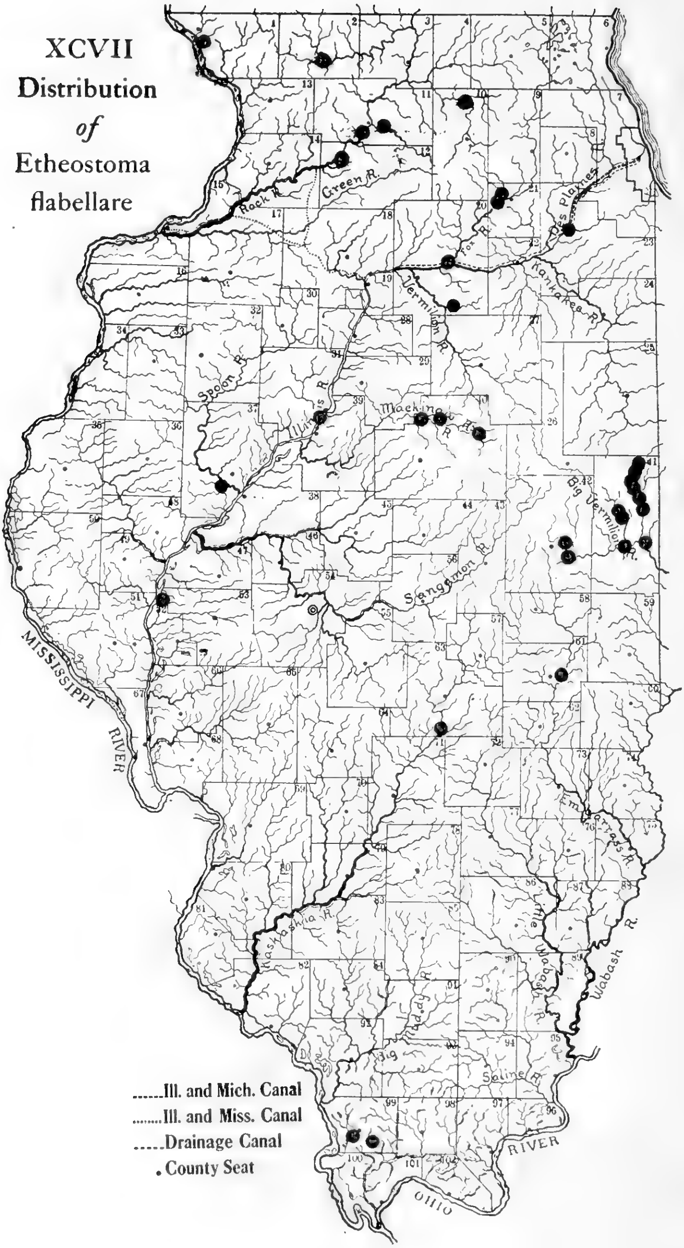

......Ill. and Mich. Canal
......Ill. and Miss. Canal
.....Drainage Canal
. County Seat



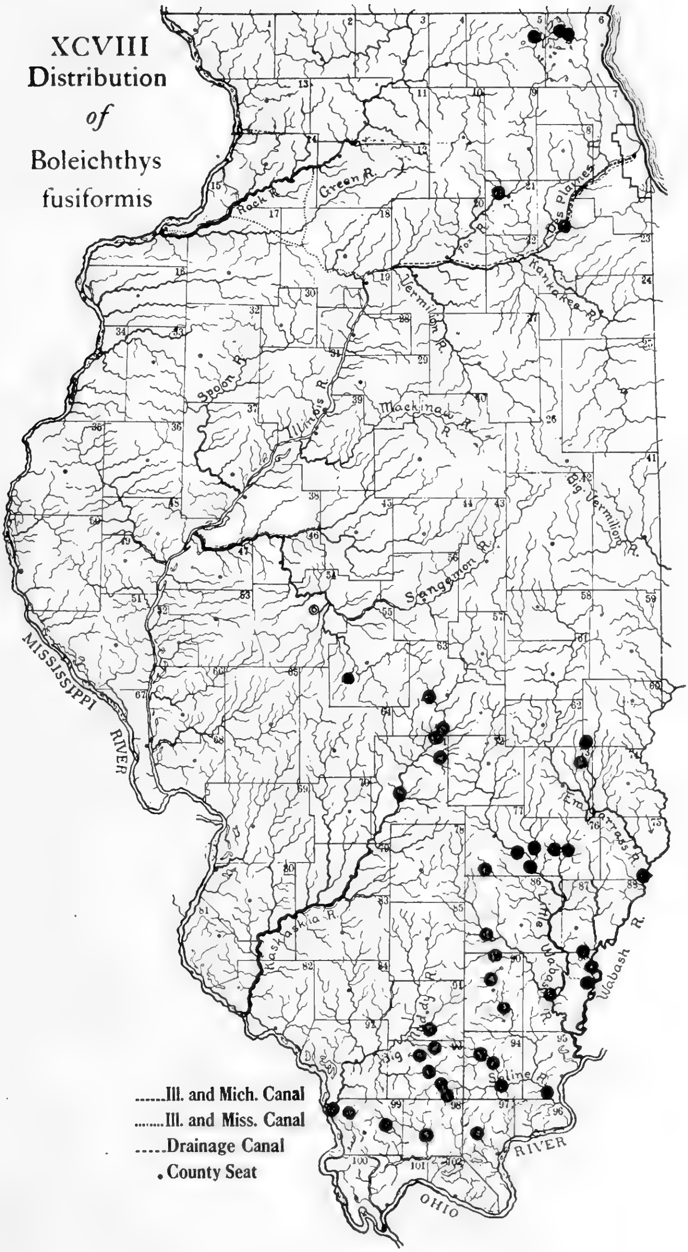

XCV
Distribution
*of*
Etheostoma
cœruleum

# XCVI
Distribution *of* Etheostoma squamiceps

XCVII
Distribution
*of*
Etheostoma
flabellare



# XCVIII
Distribution *of* Boleichthys fusiformis



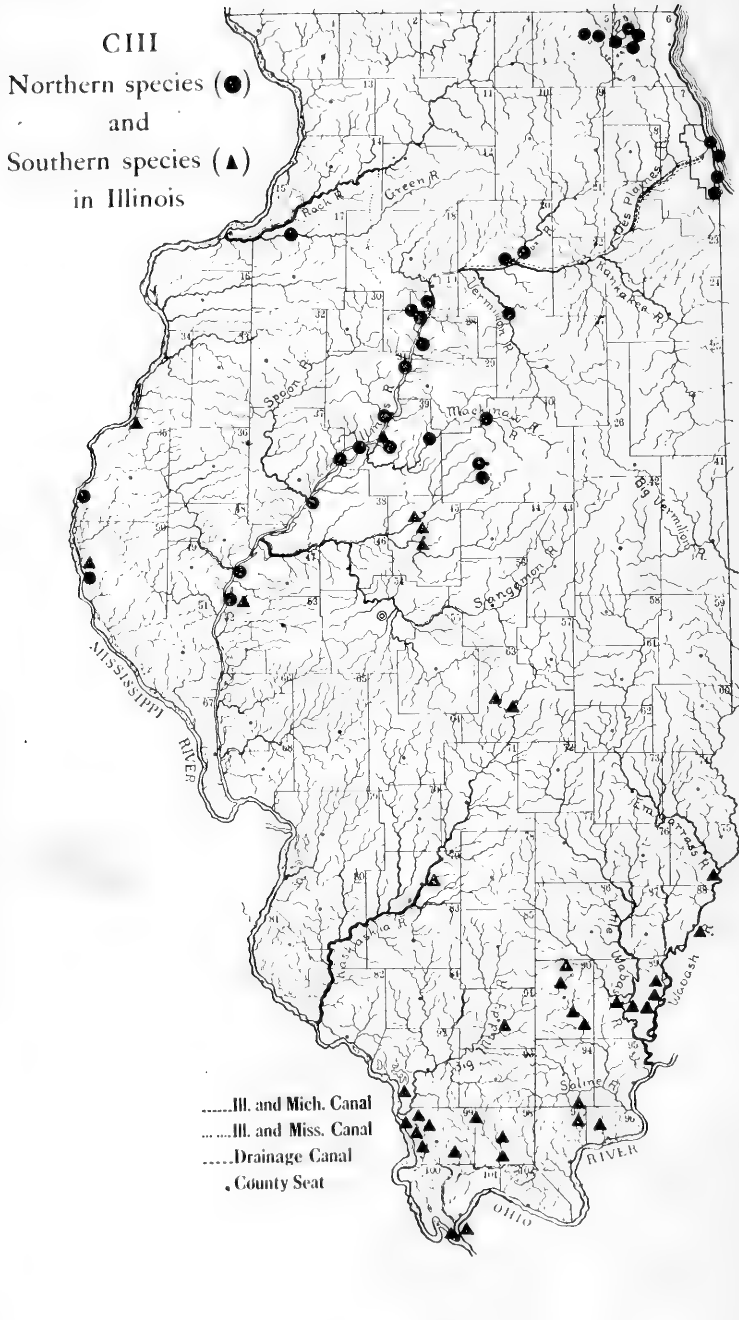
## XCIX
## Distribution *of* Microperca punctulata

C
Distribution
*of*
Roccus
chrysops

# CI
Distribution
*of*
Morone
interrupta

CII
Distribution
*of*
Aplodinotus
grunniens


......Ill. and Mich. Canal
......Ill. and Miss. Canal
....Drainage Canal
. County Seat


CIII
Northern species (●)
and
Southern species (▲)
in Illinois
Rock R.
Green R.
Des Plaines
Kankakee R.
Vermilion R.
Spoon R.
Illinois R.
Mackinaw R.
Big Vermilion R.
Sangamon R.
MISSISSIPPI RIVER
Kaskaskia R.
Embarrass R.
Little Wabash R.
Wabash
Big Muddy R.
Saline R.
OHIO RIVER
......Ill. and Mich. Canal
......Ill. and Miss. Canal
......Drainage Canal
. County Seat

# BULLETIN

OF THE

# ILLINOIS STATE LABORATORY

OF

# NATURAL HISTORY

URBANA, ILLINOIS, U. S. A.

VOL. VIII. FEBRUARY, 1910 ARTICLE IV.


## THE ECOLOGY OF THE SKOKIE MARSH AREA, WITH SPECIAL REFERENCE TO THE MOLLUSCA.




BY

FRANK COLLINS BAKER

Curator of the Chicago Academy
of Sciences

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DANVILLE, ILLINOIS

# CONTENTS.

Article IV.—*The Ecology of the Skokie Marsh Area, with Special Reference to the Mollusca.* By Frank Collins Baker.

## Introduction.

The present paper is an attempt to place on record a minute study of a small area with special reference to its molluscan inhabitants. It is believed that this is one of the first attempts to apply the ecological method, so notably used by the botanists (Cowles, 1901; Jennings, 1909, etc.), to the study of the Mollusca, although Adams (1906) and Ruthven (1904) have included this class of animals in their report of the Ecological Survey of Michigan, and Pilsbry (1905), Elrod (1901–03) and Adams (1900) have made valuable contributions to molluscan ecology. Attempts to study the mollusks of a restricted region from an ecological standpoint are, however, rare, the writer having been unable to find any papers in which these animals were studied purely from this standpoint.

It was thought that an exhaustive study of the habitat relations of all the mollusks of a given area might throw some light on their specific distinctions (especially those of the fresh-water pulmonates), and the studies herein detailed seem to warrant the belief that some good results along this line have been accomplished. These are referred to under the head of taxonomy (page 489).

### METHOD OF STUDY.

The area in question was visited once or twice a week from May 18 to September 5, 1908; some additional work was also done in 1909. Many of the stations were visited several times, and nearly all were examined twice or more. Specimens were collected from the edges of the pools and ponds as well as from the deeper parts. In the woods almost every old log and piece of rotting wood was examined, and in the dry ponds the ground was dug up in many places in search of any burrowing mollusk. All material has been carefully preserved with exact data, and now forms a part of the ecological collection of the Chicago Academy of Sciences.

It has been thought of value in this connection to list all those species of animals which have been found directly associated with the mollusks in their various habitats. Thus, if a beetle was found under bark with a mollusk it was secured and listed with the molluscan species found at this station. So, also, the aquatic insects were listed in connection with the aquatic mollusks.

As an ecological survey is not complete without a knowledge of the plant societies, the more characteristic plants have been listed in connection with the various habitats. This list does not pretend to completeness, its purpose being to indicate those species of plants most intimately associated with the molluscan habitats.

At the time the survey was made, a collection of the nesting birds of the Skokie region was secured for the museum of the Academy, and it has been thought of value to include a few notes on these.

ACKNOWLEDGMENTS.

My thanks are due to the following persons who have greatly aided in the work of the survey:

To Dr. H. C. Cowles, University of Chicago, and Miss Carrie A. Reynolds, Lake View High School, for identifying the majority of the plants; to Mr. V. E. Shelford, University of Chicago, Mr. Chas. A. Hart, of the State Laboratory of Natural History, and Mr. J. J. Davis, Assistant to the State Entomologist, for assistance in working up the insects; to Mr. A. E. Ortmann, of the Carnegie Museum, Pittsburg, for the identification of the crawfishes; and to Mr. Frank M. Woodruff and Mr. Edward R. Ford for assistance in the determination of the birds as well as for many notes and suggestions on the same.

The photographs of habitats have been made by Mr. F. M. Woodruff, of the Chicago Academy of Sciences, and the author. On each photograph the name of the photographer appears in parenthesis.

## Economic Considerations.

An area such as is herein described has a distinctly economic value, affording, as it does, both concealment and food for vertebrate life. The birds find excellent protection for their young in the thick vegetation, and abundant food is provided in the numerous ponds, streams and woodlands. The habitats are especially favorable for a large variety of avian life. The thrushes, catbirds and thrashers find nesting sites in the large number of thorn-bushes (*Cratægus*); the woodpeckers and bluebirds, in holes in the rotting trees; the rails, bitterns and marsh wrens find protection among the cattails; and the crows and hawks find nesting locations high up in the tall trees. Many low bushes harbor the nests of the summer yellowbird, the goldfinch and the indigo bird. In fact the environments obtainable here are suitable for a large majority of the nesting birds of northern Illinois.

Food is everywhere abundant. The ponds and streams as well as the woods and fields teem with invertebrate life (mollusks, insects, crustaceans), thus affording endless supplies for the sustenance of nestlings. The preponderance of insect-eating birds in this region should be gratifying to the farmers, as during the spring these birds destroy vast numbers of injurious insects—a fact which is, unfortunately, not fully appreciated by the agriculturists. The hawks and owls are also very beneficial in destroying injurious rodents. In this connection the humble snake must not be overlooked, for it is equally valuable for this purpose. A number of birds were observed to feed on crawfish and also to feed their young on this crustacean. The stomachs of the young of the green heron and American bittern contained crawfish of large size, as did also the stomachs of the parent birds. The great blue heron, green heron, American bittern, and a single specimen of the fish-hawk were observed fishing in the East Branch of the Chicago River, evidently for crawfish, which are very abundant in this stream. Stomach pellets from the screech-owl were also observed to contain the remains of crawfish.

It would seem eminently desirable that in a farming district, tracts of land similar to those recorded below should be preserved, that the birds may be allowed to nest unmolested; and the agriculturist should be impressed with the value of these animals as destroyers of noxious insects, especially during the nesting season.

## General Topography.

If a map of the Chicago area as it appeared during Pleistocene time be examined, the following features will be noted in the northern part of the region, in the vicinity of Glencoe.

## Explanation of Fig. 1.

A. Map of area surveyed—from Glencoe west to Shermerville, a distance, east and west, of three miles. The width of the map (north and south) represents one mile.

1–36. Stations studied.

37. Chicago, Milwaukee and St. Paul Railroad passing through Shermerville.

38. Chicago and Northwestern Railroad cut-off.

39. Chicago and Northwestern Railroad passing through Glencoe.

40. Chicago and Milwaukee Electric Railroad.

Large trees and virgin forest.

Shrubs and small trees.

Swamp.

Houses.

Roads.

Small ponds and pools.

Unmarked spaces indicate open fields.

This map is based on the Highwood topographic sheet of the United States Geological Survey.

B. Profile section from Glencoe to Shermerville (the vertical scale is much exaggerated, in comparison with the longitudinal scale). 630, 670, etc., altitudes above sea-level.

1. East Arm of Skokie Bay.
2. West Arm of Skokie Bay.
3. Small bay west of Skokie Bay.

A. Skokie Marsh.

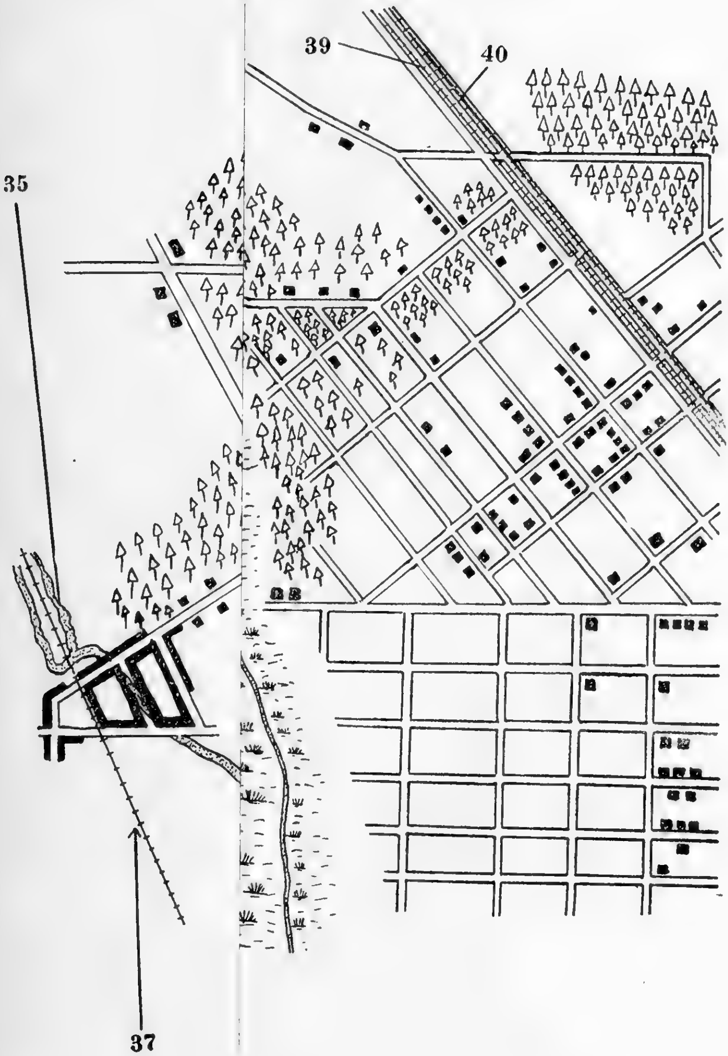
B. Intermediate Ridge.

C. East Branch of the Chicago River.

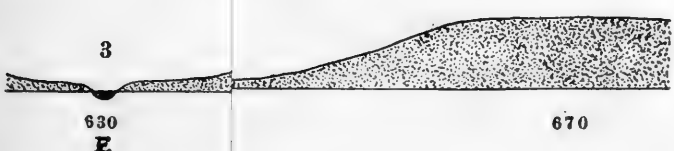
D. Glenwood Beach Ridge.

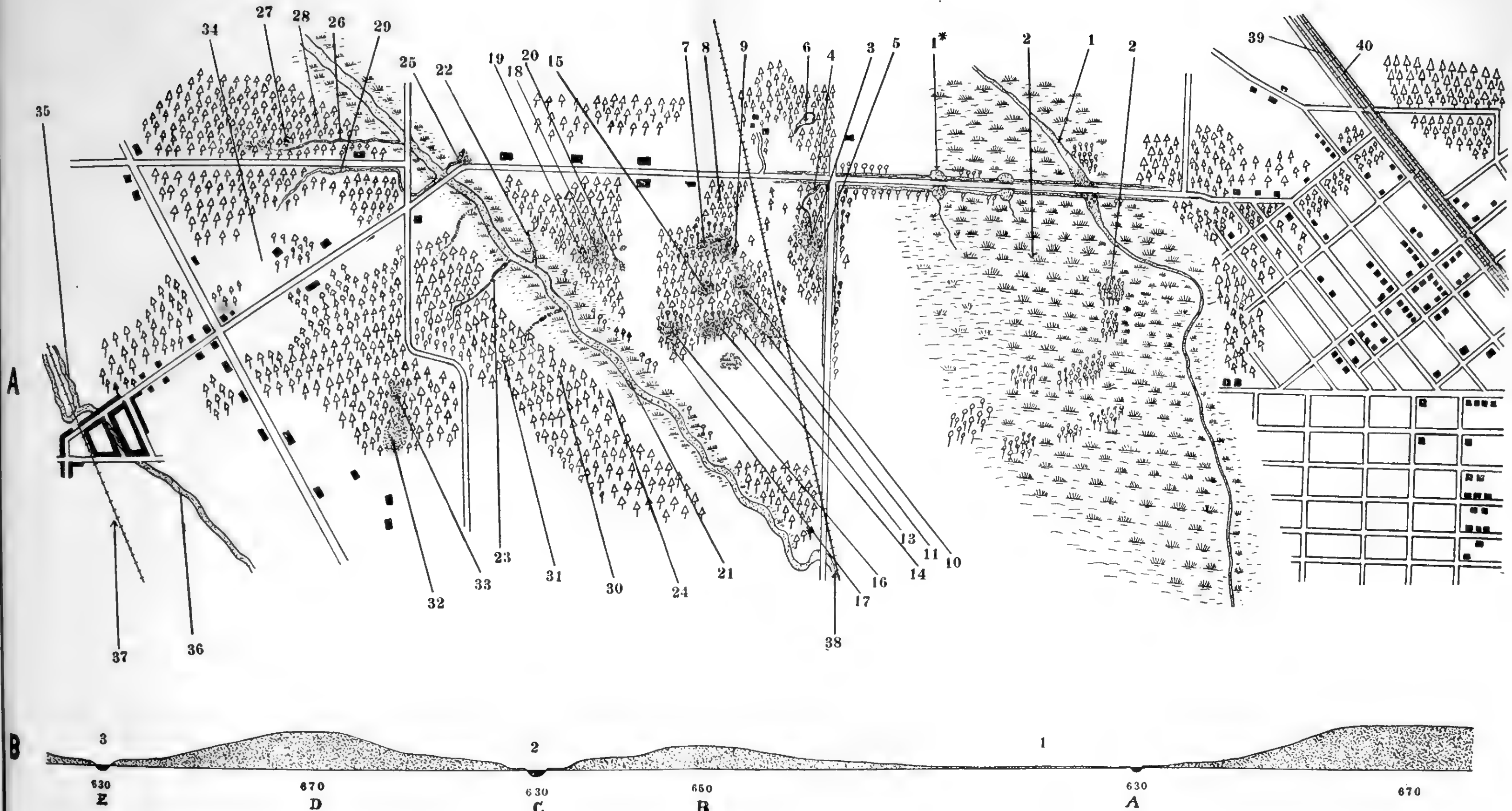
E. North Branch of the Chicago River.

A




B





A
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11
10
B
3
2
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630
670
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FIGURE 1.

A rather large bay, called Skokie Bay, extended northward for a considerable distance. It is this ancient Skokie Bay which, when the ice-sheet had retreated to such an extent that Lake Chicago (now Lake Michigan) no longer discharged its waters by way of the Desplaines-Illinois rivers, became partly drained and now forms the region familiarly known as the Skokie Marsh. A second bay lay to the west of Skokie Bay. A glance at the cross-section on the map (Fig. 1) will show the relation of Skokie Bay to this small bay, the Glenwood ridge separating the two. It seems evident, that at a stage later than the time at which the Glenwood ridge was formed, there must have been a period when Skokie Bay was itself divided into two arms. This condition is very plainly marked in the topography of the country, the ridge between the east and west shores of Skokie Bay being one of the conspicuous features of the landscape, especially at its highest point, overlooking the East Branch of the Chicago River. This ridge attains an elevation of twenty feet above the surface of the stream. The height of the Glenwood ridge in this area is 670 feet, or twenty feet above the ridge previously mentioned. The cross-section shows the relation of these three elevations. The view of the Skokie Marsh from the top of the highest ridge at the western edge of the town of Glencoe, is really quite picturesque, and on a bright, cool morning in early spring is sure to leave a lasting and pleasing impression.

The recession of the water of Skokie Bay has left some peculiar topographic features: the bed of the bay proper (see map and section) is now the Skokie Marsh; the surface of the ridge, which divided Skokie Bay into two arms and which was probably a long sand spit, contains a large number of pools of various sizes, which are more or less dry in the summer and fall; this area is rather sparsely wooded; the smaller arm of Skokie Bay is now occupied by the East Branch of the North Branch of the Chicago River; the small bay to the west of Skokie Bay is now occupied by the North Branch of the Chicago River, while the ridge between these two streams, which is believed to be equivalent to the Glenwood beach, is heavily wooded, with but few of the small pools so characteristic of the lower ridge to the east.

The area surveyed, which is three miles long and one mile wide, is thus seen to comprise five rather distinct areas, which may be designated as A, B, C, D and E.

### *A. Skokie Marsh.*

(Plate VI.)

A strip of low, marshy land, about one mile in width, through which a small stream flows in the spring and early summer. In late summer and fall this stream is reduced to a series of pools separated by dry land. The marsh, which is covered with water from a few inches to several feet in depth in spring, becomes dried out in the fall and the ground becomes hard and sun-cracked. The marshy area is open, for the most part, and is covered with a thick growth of cattails and other aquatic vegetation, while toward the margins a tall, thick growth of swamp grass (*Calamagrostis*) succeeds the reeds. The marsh is dotted here and there with many small "islands" composed of several species of marsh-loving trees (see Fig. 1). These "islands" are surrounded by a dense growth of cattails, which attain a height of over ten feet and are very difficult to penetrate. The Glencoe road crosses the marsh, and on either side a rather deep ditch has been made, which is filled with aquatic plants. In two places these ditches form a large, deep, circular basin, connecting the ditches and spanned by a low bridge. The stream also widens as it flows under the Glencoe road bridge, forming a wide, deep pool. In the fall these ditches become more or less dry, and the basins are reduced to small pools.

### *B. Intermediate Ridge or Sand Spit.*

A triangular piece of territory about a mile wide, lying west of the Skokie Marsh. The ground is from ten to twenty feet above the surface of the stream and is well wooded for the most part. The slope on the eastern face of this ridge is very gradual, but on the west it is quite abrupt, forming a rather steep terrace bordering the East Branch of the Chicago River. Scattered throughout this area are numerous depressions of various sizes, from a few feet to two hundred feet or more in diameter. These are of varying depth, from a few inches to several feet. In the spring they are filled with water and support a varied fauna and flora, but in the summer they dry up wholly or partially. These may be termed summer-dry ponds or pools—a name which seems more comprehensive than the word swale, which is used in the eastern states. About a dozen such ponds were examined in this area and careful notes were made of their biotic contents.

This triangular area divides naturally into three subordinate areas: one beside the road running at right angles with the Glencoe road and between this and the Northwestern Railroad cut-off; one west of the railroad; and one bordering the East Branch of the Chicago River and separated from the second area by a field about three hundred feet in width. The first area is a few feet above the Skokie Marsh stream, the second is on rising ground, and the third is on an elevation twenty feet above the river. A large part of the southern portion of this area is cleared for grazing purposes.

### C. *The East Branch of the Chicago River.*

(Plates XVII.,2, and XVIII.,1.)

This stream is quite wide in the spring, and is from one to six or more feet in depth. It occupies a little valley with a rather broad flood-plain flanked on either side by abrupt ridges about ten feet high, forming, in this part of the area, distinct terraces. The river meanders considerably and also varies in width and depth. The latter is shown plainly in the late summer, when the river is reduced to a succession of small, muddy pools, varying from a few inches to three or four feet in depth (Plate XVIII., 1). The river may be properly termed an intermittent stream.

The flood-plain varies in width from a few feet to two or three hundred feet. It is covered with swamp grass, interspersed with reeds in the lower places. Trees have invaded this area, and such species as the swamp white oak and maple are abundant on the broader portions, in some places forming large groves, or thick tangles—as where the button-bush borders the river near the southern end of the area in question. In several places the river spreads over the entire flood-plain, forming a characteristic bog. In most places, however, the river occupies little territory outside of its bed, except in times of very high water.

### D. *Glenwood Beach Ridge.*

(Plate XXII.)

This area lies west of the East Branch of the Chicago River, between this branch and the North Branch. The beach reaches an elevation of 670 feet, or forty feet above the river, and twenty feet higher than the ridge on the east side of the East Branch. This region is rather heavily timbered, the trees being large and the ground being covered with an accumulation of debris, showing that the area has not been disturbed by man. About a third of a mile west of the East Branch a large ridge is encountered which is very abrupt, rising suddenly from a level plain and gradually sloping toward the south until it reaches the level of the surrounding area. This was probably a sand spit extending into Skokie Bay. Small ponds, like those found in the area east of the East Branch, are generally absent, although there are several ponds and semi-marshy spots at the foot of the sand spit mentioned above. Several small streams drain into the East Branch during the spring, but aside from these, this area is quite free from summer-dry ponds, owing, probably, to its greater elevation and the absence of large depressions in which water might gather.

To the south, this territory is cleared for pasture and farm land, and the same may be said of the areas bordering the Shermerville road, which cuts through this portion of the region. Bordering the river to the north, the ground is lower and forms a wet, marshy area in spring. This is especially true of those portions of the territory to the north of the Glencoe road.

### *E. The North Branch of the Chicago River.*

(Plate XVIII., 2.)

This stream, which is not of an intermittent character as is the East Branch, is from twenty to thirty feet in width and is quite deep. It flows through a low area, the banks also being low, just a foot or so above the stream, and the territory on either side is swampy and reed-grown. East of the St. Paul railroad bridge, the river forms an extensive arm at the foot of the railroad embankment, which is marshy and supports a fauna different from that of the river proper. The river flows through the village of Shermerville and is becoming contaminated with sewage, like the larger stream at the southward. This area was found to be very poor biologically.

### Seasonal Comparisons.

The area herein discussed is typical of many in the middle west, especially in those states bordering the southern part of Lake Michigan. It is typical also of those areas in which the volume of water fluctuates through the seasons of the year as well as in the same season in different years. In spring, there is an abundance of water in all the streams and ponds, and every depression in the woods (as shown in Plate XVI.) is filled with water and supports some kind of animal life. Spring conditions are shown in plates XVII., XVI.,2, XX., XXIII., and XVIII.,2. In the fall the water evaporates, either entirely or to such an extent as to leave only small pools here and there. This condition is shown in plates XVII.,1, XVIII.,1, and XXIV.,1, which should be compared with the photographs of the same habitats in spring.

The difference in one year as compared with another may be seen by comparing plates XVII.,1, and XXIV.,1, which were taken September 5, 1908, with plates XVI. and XXIII., of the same habitats, taken September 10, 1909. It will be recalled that the year 1908 was much drier than 1909, this difference in precipitation causing a marked effect on the summer-dry ponds of this area. The year 1909 has, therefore, been much the more favorable year for invertebrate life in these ponds and streams, owing to the less rigorous conditions of the environment. The effect has also been notably different on the vegetation, which was much more luxuriant in the fall of 1909 than at the same period in 1908.

---

The five areas just described break up into a number of more or less distinct stations, the biota of which differ more or less. These stations will next be taken up in detail. Their positions may be ascertained by consulting the map.

## A. SKOKIE MARSH. (Stations I and II.)

### Station I.

(Plate VI.)

Skokie stream and tributary ditches. This stream was once a tributary of the East Branch, but it now ceases to exist at a point southwest of Glencoe. It is an intermittent stream, in the spring being about five feet in width and from knee to waist deep. In certain spots, as at the bridge over which the Glencoe road passes, it widens to form a pool twenty feet in diameter and from six to eight feet in depth. The ditches are about five feet wide and two or three feet deep. In two places (1*) the ditches form wide pools ten or fifteen feet in diameter and six to ten feet in depth.

The characteristic plant life is as follows:

*Chara* sp. In the deep pool.
*Polygonum muhlenbergii.* In the ditches in a few inches of water.
*Sagittaria latifolia.* In shallow water.
*Iris versicolor.* In shallow water.
*Sparganium eurycarpum.* In shallow water.
*Typha latifolia.* On edge of pool.
*Salix longifolia.* A heavy clump bordering the deep pool, north of the Glencoe road.

The animal life observed was as follows.

### Mollusks (Fluviatile Species).

*Musculium partumeium.*
*Physa gyrina.*
*Planorbis trivolvis.*
*Segmentina armigera.*
*Lymnæa reflexa.*

### Insects.

| | |
|---|---|
| *Limnotrechus marginatus.* | Water-strider. |
| *Corixa interrupta.* | Water-boatman. |
| *Notonecta undulata.* | Back-swimmer. |
| *Hydroporus undulatus.* | Diving beetle. |
| *Dytiscus* larva. | Larva of diving beetle. |
| *Culex* sp. | Mosquito. |
| *Libellula basalis.* | Dragonfly (adult). |
| *Anax junius.* | Dragonfly (nymph). |
| *Zaitha fluminea.* | Water-bug. |

### Lower Vertebrates.

| | |
|---|---|
| *Ameiurus melas.* | Black Bullhead. |
| *Esox lucius.* | Pickerel. |
| *Rana pipiens.* | Leopard-frog. |
| *Natrix grahami.* | Water-snake. |

## Station II.

(Plates VII. and VIII.)

The open marsh. It is about a mile in width. In the spring the whole surface is covered with water which is from a few inches to several feet in depth. In the late summer and fall this area is either entirely dry or with only a few shallow pools distributed over the surface. Scattered over the marsh are numerous forest islands from fifteen or twenty feet to over two hundred feet in diameter. Some of these are irregularly round in outline; the largest ones, however, are of an oblong shape.

There are three distinct plant societies in the marsh, which may be characterized as follows.

### I. THE FOREST ISLANDS SOCIETY.

| | |
|---|---|
| *Populus tremuloides.* | American Aspen. |
| *Ribes floridum.* | Wild Black Currant. |
| *Salix longifolia.* | River-bank Willow. |

### II. THE TYPHA LATIFOLIA SOCIETY.

Cattails surround the forest islands, often reaching a height of ten feet or more, presenting an almost impenetrable jungle. In several places small areas of cattail islands occur, and the ditches and streams are lined with *Typha*.

### III. THE IRIS VERSICOLOR-CALAMAGROSTIS CANADENSIS SOCIETY.

The greater part of the swamp is covered with these two plants, interspersed here and there with clumps of *Sagittaria latifolia*, *Sparganium eurycarpum*, *Sium cicutæfolium* and *Eupatorium purpureum*.

The bluejoint grass (Pl. VIII., 2) reaches a height of eight feet or more, affording excellent concealment for the nests of marsh-inhabiting birds.

## THE FAUNA OF THE MARSH.

### INSECTS.

With the addition of a few small beetles in the fall, the insect fauna of the marsh is the same as that of the ditches and stream.

### MOLLUSKS.

#### FLUVIATILE SPECIES.

*Physa gyrina.* Very abundant.
*Lymnæa reflexa.* Rare.

LAND SPECIES.

*Succinea retusa.* Very abundant.
*Succinea avara.* Less abundant.
*Agriolimax campestris.* Abundant.

No difference could be detected between the mollusk fauna of the marsh and that of the forest islands except in the distribution of *Agriolimax campestris*, which was found only about the trees of the islands.

BIRDS.

During the nesting season the following birds are more or less abundant:

| | |
|---|---|
| Blue-winged Teal. | Nesting site not located. |
| American Bittern. | Nesting among cattails. |
| Least Bittern. | |
| Great Blue Heron. | Nesting site not located. |
| King Rail. | Nesting among cattails. |
| Virginia Rail. | Nesting among cattails. |
| Sora. | Nesting among cattails. |
| Florida Gallinule. | Nesting among cattails. |
| Marsh Hawk. | Nesting in marsh. |
| Kingbird. | Nesting on forest islands. |
| Traill's Flycatcher. | Nesting on forest islands. |
| Bobolink. | Nesting on border of marsh. |
| Dickcissel. | Nesting on border of marsh. |
| Red-winged Blackbird. | Nesting in marsh. |
| Swamp Sparrow. | Nesting on border of marsh. |
| Song Sparrow. | Nesting on border of marsh. |
| Grasshopper Sparrow. | Nesting on border of marsh. |
| Leconte's Sparrow. | Nesting on border of marsh. |
| Field Sparrow. | Nesting on border of marsh. |
| Savannah Sparrow. | Nesting on border of marsh. |
| Catbird. | Nesting on forest islands. |
| Short-billed Marsh Wren. | Nesting in marsh. |
| Long-billed Marsh Wren. | Nesting in marsh. |

## B. THE INTERMEDIATE RIDGE OR SAND SPIT.

(STATIONS III–XX.)

(Plate IX.)

A low, wet area, on the western edge of the Skokie Marsh. It is well wooded, many of the trees being of large size. A rather wide opening extends diagonally through this area, and is occupied by a summer-dry pond. In the spring the pond is from one to two feet in depth and there are several small streams which flow through the wooded portion, in which there are also many small pools in depressions of greater or less size. These afford good habitats for a number of mollusks.

The flora of this region comprises a number of distinct plant societies which may be classed as follows.

(1). That of the central nucleus, the pond, which provides a habitat for

| | |
|---|---|
| *Typha latifolia.* | Cattail. |
| *Iris versicolor.* | Large Blue Flag. |
| *Asclepias incarnata.* | Swamp Milkweed. |

(2). That at the edge of the pond, which is marked by the presence of

| | |
|---|---|
| *Salix longifolia.* | River-bank Willow. |
| *Ulmus americana.* | American Elm. |
| *Quercus bicolor.* | Swamp White Oak. |

This plant society is closely encroaching upon the first society, and will ultimately exterminate it by invading the entire area.

(3). The large forest-trees form a distinct society which follows closely upon the society mentioned above. The trees are of large size, showing that the area has been untouched by man. The following species comprise the dominant types:

| | |
|---|---|
| *Ulmus americana.* | American Elm. |
| *Tilia americana.* | Basswood. |
| *Cratægus punctata.* | Large-fruited Thorn. |
| *Cratægus mollis.* | Red-fruited Thorn. |
| *Corylus americana.* | Hazelnut. |
| *Quercus bicolor.* | Swamp White Oak. |
| *Carya ovata.* | Shellbark Hickory. |

(4). The ground beneath the forest growth is carpeted with low-growing plants, among which the following species are conspicuous:

| | |
|---|---|
| *Arisæma dracontium.* | Green Dragon. |
| *Campanula americana.* | Tall Bellflower. |
| *Cicuta maculata.* | Water Hemlock. |
| *Osmorrhiza longistylis.* | Smoother Sweet-Cicely. |
| *Rudbeckia laciniata.* | Green-headed Coneflower. |

The entire area is an excellent example of plant succession.

The poison ivy or poison oak (*Rhus radicans*) grows luxuriantly on the western edge of this area.

## Station III.

This includes the pond, and also the ditches within this region.

INSECT LIFE.

| | |
|---|---|
| *Limnotrechus marginatus.* | Water-strider. |
| *Corixa interrupta.* | Water-boatman. |
| *Notonecta undulata.* | Back-swimmer. |
| *Culex* sp. | Mosquito. |
| *Zaitha fluminea.* | Water-bug. |
| *Libellula basalis.* | Dragonfly (adult). |

MOLLUSKS.

FLUVIATILE SPECIES.

*Musculium partumeium.* Occasional.
*Physa gyrina.* Very abundant.
*Segmentina armigera.* Very abundant.
*Planorbis trivolvis.* Common.
*Lymnæa reflexa.* Common.

LAND SPECIES.

*Succinea retusa.* Common.
*Succinea avara.* Occasional.

## Station IV.

A small stream which drains from ditch beside Glencoe road into the center pond. Also, hollows in the wooded area which are filled with water in the spring. In the fall, all of these habitats are dry, and the dead shells of mollusks may be found scattered over the surface or under dead leaves.

MOLLUSKS.

FLUVIATILE SPECIES.

*Sphærium occidentale.* Very abundant.
*Aplexa hypnorum.* Very abundant.
*Physa gyrina.* Occasional.
*Segmentina armigera.* Very abundant.
*Planorbis parvus.* Rare.
*Lymnæa caperata.* Occasional.
*Lymnæa parva sterkii.* Rare.

LAND SPECIES.

*Succinea retusa.* Common.
*Succinea avara.* Occasional.

## Station V.

The wooded area. The ground beneath the trees is covered with leaves, dead twigs, old logs and other wood debris, which afford cover for the following species of land shells:

*Succinea ovalis optima.* Plentiful.
*Succinea avara.* Plentiful.
*Zonitoides arboreus.* Common.
*Vitrea hammonis.* Rare.
*Polygyra fraterna.* Very common.
*Polygyra albolabris.* Rare.
*Polygyra thyroides.* Very common.
*Pyramidula alternata.* Common.

The larger Polygyras appear to frequent the base of large trees, while the smaller species are common under the forest debris and leaves. *Succinea ovalis* is plentiful under old leaves. *Pyramidula alternata* and *Polygyra fraterna* prefer to hide under "started" bark on dead stumps and logs, in company with the large beetle *Osmoderma scabra.* Of twenty-one specimens of *Polygyra thyroides*, five individuals had a pronounced denticle on the parietal wall. The specimens of *Succinea ovalis optima* vary greatly in the height of the spire and in the width of the last whorl.

### ANIMALS ASSOCIATED WITH THE MOLLUSCA.

#### INSECTS.

| | |
|---|---|
| *Osmoderma scabra.* | Beetle; under bark. |
| *Melanotus communis.* | Beetle; under bark. |

#### CRUSTACEA.

| | |
|---|---|
| *Cambarus blandingi acutus.* | Crawfish. |

#### LOWER VERTEBRATES.

| | |
|---|---|
| *Eutænia sirtalis.* | Garter-snake. |
| *Storeria occipitomaculata.* | Storer's Snake. |

#### BIRDS.

Red-headed Woodpecker.
Northern Flicker.
Chimney Swift.
Blue Jay.
Crow.

Cowbird. Young; in yellow warbler's nest
Song Sparrow.
Indigo Bunting; nesting.
Northern Yellow-throat.
Yellow Warbler; nesting.
Red-eyed Vireo.
Catbird; nesting.
Brown Thrasher; nesting.
Wood Thrush; nesting.
American Robin; nesting.

## Station VI.

Clay hole about twenty feet in diameter in woods on west edge of Skokie Marsh, north of Glencoe road. The pool is almost circular in outline, but a ditch-like depression has been formed on the southwest edge, which extends irregularly for some forty or fifty feet. There is no vegetation in or about the pool. *Physa* inhabited the pool by thousands, all, however, being immature. During a visit in July they were observed to form a dark border about three inches in width entirely around the pool. In the ditch-like outlet fully adult Physas were found, as well as *Planorbis*.

Only two species were found, the *Physa* being by far the most abundant. These were

*Physa gyrina*,
*Planorbis trivolvis*.

During the summer and fall, the ditch-like outlet is dry. In the clay pit no Planorbes were found, and only immature *Physa*. In the ditch-like depression were the dead shells of *Planorbis* and of adult *Physa*. Old shells of the latter were marked with four well-defined varices, indicating rest periods.

## Station VII.

(Plates X., XI. and XII.,1.)

A marshy pond about three hundred feet in greatest diameter, west of the Northwestern Railroad cut-off. The pond is roundly ovate in shape. In the spring the water is from one to three or four feet in depth, but in late summer and fall the pond is reduced to a number of isolated pools here and there and a small wet area in the center.

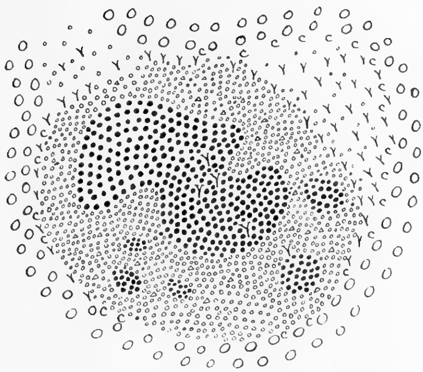


FIGURE 2.

Diagram showing relation of characteristic vegetation of Station VII. The zonal arrangement is notable.

● Typha latifolia.
o Iris versicolor.
△ Sagittaria latifolia.
Y Salix longifolia.
C Cratægus, Pyrus and Viburnum.
O Quercus, Carya, Ostrya and Populus, the oaks predominating.

The vegetation is divided into a central area and more or less distinct concentric zones of plant societies (Fig. 2), which may be described as follows.

(1). A nucleus of cattails, *Typha latifolia.*

(2). First zone, a wide expanse of reeds, *Iris versicolor*, interspersed with *Sagittaria latifolia* and *Sparganium eurycarpum.*

(3). Second zone, consisting of bush-like trees, as follows.

| | |
|---|---|
| *Cratægus punctata.* | Large-fruited Thorn. |
| *Cratægus tomentosa.* | Pear Thorn. |
| *Cratægus coccinea.* | Scarlet Thorn. |
| *Pyrus coronaria.* | American Crab-apple. |
| *Viburnum lentago.* | Nanny-berry. |
| *Salix longifolia.* | River-bank Willow. |

(4). Third zone, the forest proper, containing

| | |
|---|---|
| *Quercus macrocarpa.* | Mossy-cup, or Bur Oak. |
| *Populus tremuloides.* | American Aspen. |
| *Ostrya virginiana.* | Hop Hornbeam or Ironwood. |
| *Quercus bicolor.* | Swamp White Oak. |
| *Carya ovata.* | Shellbark Hickory. |

The western end of the pond is free from reeds, is very shallow, and supports the following marsh-loving plants:

| | |
|---|---|
| *Proserpinaca palustris.* | Mermaid-weed. |
| *Ranunculus multifidus.* | Yellow Water-Crowfoot. |
| *Sium cicutæfolium.* | Hemlock Water-Parsnip. |

*Ranunculus multifidus* covers the bottom of the pond everywhere, in the deeper as well as in the shallower portions.

The invertebrate life of this station is quite varied*. The following species were observed.

INSECTS.

| | |
|---|---|
| *Limnotrechus marginatus.* | Water-strider. |
| *Corixa interrupta.* | Water-boatman. |
| *Notonecta undulata.* | Back-swimmer. |
| *Zaitha fluminea.* | Water-bug.† |
| *Libellula basalis.* | Dragonfly (adult). |
| *Hydroporus undulatus.* | Diving beetle. |

CRUSTACEA.

| | |
|---|---|
| *Cambarus blandingi acutus.* | Crawfish. |

MOLLUSKS.

Molluscan life was quite abundant in the pond. *Lymnæa* was found plentifully on dead pieces of cattails and reeds, many having hibernated on the stems of the reeds, two to four inches above the water; other individuals were found in the water attached to the submerged base of the cattails. The Lymnæas were not found in open patches of water where no cattails grew. *Planorbis* occupied the same habitat as *Lymnæa*. *Physa* was rare in this area. *Succinea* was plentiful on the stems of cattails near the water. *Seg-*

*The vertebrate life of stations VII–XVII, is listed on page 468.

†This water-bug preys upon mollusks. Mr. B. F. Isely, of Tonkawa, Oklahoma, has observed it feeding upon *Physa* in an aquarium, large numbers of the snail being eaten.

*mentina*, as well as *Musculium*, was common in open spaces in the pond.

The following species were secured.

FLUVIATILE SPECIES.

*Musculium partumeium*. Common.
*Physa gyrina*. Common.
*Segmentina armigera*. Common.
*Planorbis trivolvis*. Common.
*Lymnæa reflexa*. Common.

LAND SPECIES.

*Succinea retusa*. Common.

## Station VIII.

Woods surrounding Station VII. The ground is high and dry, the trees are rather far apart, producing an open woodland effect. The ground is covered with dead leaves, rotting logs and stumps, and the various debris found in such a habitat. The ground about the pond is quite high and the slope pondward is rather abrupt. *Polygyra albolabris* was found in fair numbers in holes in logs and stumps and under old logs; *Polygyra fraterna* was common under logs and "started" bark; the smaller land snails were plentifully distributed in old stumps and on chips and other small debris; while *Succinea ovalis* was common under dead leaves in small hollows. *Zonitoides* was plentiful under "started" bark.

The following species were secured.

LAND MOLLUSKS.

*Polygyra albolabris*. Occasional.
*Polygyra fraterna*. Common.
*Pyramidula alternata*. Rare.
*Agriolimax campestris*. Common.
*Zonitoides arboreus*. Common.
*Succinea avara*. Rare.
*Succinea ovalis*. Common.

INSECT LIFE.

| | |
|---|---|
| *Ceuthophilus* sp. | Cricket; under log with land shells. |
| *Pterostichus permundus*. | Beetle; under log with land shells. |

## Station IX.

A small pool to the southeast of Station VII, and connected with that habitat by an area of low swampy ground, forming a depression in the high ground surrounding Station VII. Area about fifteen by twenty-five feet. The vegetation is the same as that of Station VII.

This station is carpeted with

| | |
|---|---|
| *Ranunculus multifidus.* | Yellow Water-Crowfoot. |
| *Proserpinaca palustris.* | Mermaid-weed. |

The following mollusks were observed, *Physa gyrina* being the predominating species.

FLUVIATILE SPECIES.

*Sphærium occidentale.* Rare.
*Musculium partumeium.* Common.
*Physa gyrina.* Abundant.
*Planorbis trivolvis.* Common.
*Segmentina armigera.* Common.
*Lymnæa reflexa.* Rare.

LAND SPECIES.

*Succinea retusa.* Common.
*Agriolimax campestris.* Common.

*Lymnæa reflexa* is a migrant from Station VII.

## Station X.

A small pond about thirty feet in diameter, almost circular in outline, two hundred or more feet from the larger pond (Station VII), and connected with that station by a narrow stream of water. The pond hole is from six inches to two feet in depth, and the bottom is composed of soft, tenacious, clayey mud. In the spring the hole is filled with water, but during the summer and fall the water evaporates, leaving the mud in hard, irregular cakes, the cracks between being filled with vegetation. The mollusks find a retreat in these cracks, into which they crawl and æstivate. An epiphragm is formed, as in the helices, and many individuals are thus enabled to survive the dry summer, to be revived in the late fall when the rains begin, thus providing for the perpetuation of the species. *Physa gyrina* is the most abundant species in this station, the dead shells being scattered over the mud and in the cracks in endless profusion. Only about three per cent. of the shells contained living animals.

The vegetation of this station is as follows.

On the Dry Bottom.

| | |
|---|---|
| *Ranunculus multifidus.* | Yellow Water-Crowfoot. |

About the Border.

| | |
|---|---|
| *Iris versicolor.* | Large Blue Flag. |
| *Cratægus punctata.* | Large-fruited Thorn. |
| *Tilia americana.* | Basswood. |
| *Ulmus americana.* | American Elm. |

Mollusks as listed below were obtained.

FLUVIATILE SPECIES.

*Musculium partumeium.* Common.
*Physa gyrina.* Very abundant.
*Segmentina armigera.* Rare.

LAND SPECIES.

*Succinea retusa.* Rare.

INSECTS.

| | |
|---|---|
| *Notonecta undulata.* | Back-swimmer. |
| *Corixa interrupta.* | Water-boatman. |
| *Zaitha fluminea.* | Water-bug. |

## Station XI.

A small stream, dry in summer, extending from Station X, in a curved direction, to the railroad embankment. The bed of the stream is about a foot in width, but in the spring the water covers the area to a width of from two to five feet.

The following plants were noted in the immediate vicinity:

| | |
|---|---|
| *Onoclea sensibilis.* | Sensitive Fern. |
| *Ribes floridum.* | Wild Black Currant. |
| *Cratægus punctata.* | Large-fruited Thorn. |
| *Carya ovata.* | Shellbark Hickory. |
| *Sium cicutæfolium.* | Hemlock Water-Parsnip. |
| *Quercus bicolor.* | Swamp White Oak. |
| *Caltha palustris.* | Marsh Marigold. |
| *Anemone canadensis.* | Canada Anemone. |

Mollusks of the following species were secured, all fluviatile:

*Sphærium occidentale*. Rare.
*Musculium partumeium*. Common.
*Segmentina armigera*. Common.
*Aplexa hypnorum*. Very common.
*Physa gyrina*. Common.
*Lymnæa caperata*. Common.
*Lymnæa reflexa*. Rare.

*Lymnæa reflexa* is undoubtedly a migrant from Station VII, probably floated down during high water. But two specimens were found after a careful search.

## Station XII.

Woods bordering Station XI. The ground is low and consequently wet in spring. *Succinea ovalis* was observed on leaves of various plants, four to five feet from the ground. It was also found under dead leaves. In summer this area is dry and the ground is quite hard.

The following land mollusks were secured:

*Succinea avara*. Rare.
*Succinea retusa*. Rare.
*Succinea ovalis*. Common.
*Polygyra thyroides*. Uncommon.
*Polygyra fraterna*. Common.

## Station XIII.

Wet portions of woods connecting stations XII and XIV, evidently fed by overflow from Station XIV.

Vegetation the same as that of Station XI.

The following species of mollusks, all fluviatile, were secured. Of the first three species, the *Lymnæa* was the least abundant and the *Aplexa* the most abundant.

*Sphærium occidentale*. Common.
*Aplexa hypnorum*. Very common.
*Lymnæa caperata*. Uncommon.
*Planorbis exacuous*. Rare.

## Station XIV.

(Plates XII.,2, and XIII.)

A small pond about thirty feet in diameter, rather pyriform in shape. The water is knee to waist deep in the spring, but in the fall it is reduced to a small area in the center. The plant societies here form into zones, as in Station VII, though not with the same regularity (Fig. 3). There is a central portion (see Pl. XII.,2) which

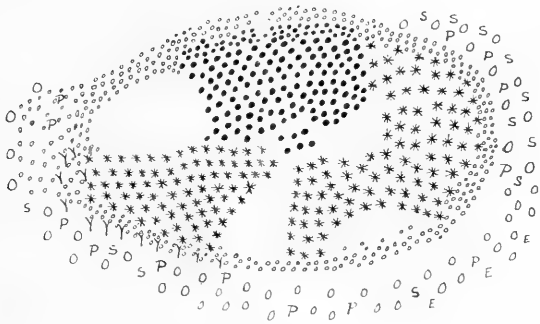


FIGURE 3.

Diagram showing relation of characteristic vegetation of Station XIV. The arrangement of Typha and Cephalanthus in distinct associations is noteworthy.

| | |
|---|---|
| * | Cephalanthus occidentalis. |
| ● | Typha latifolia. |
| o | Iris versicolor. |
| O | Quercus. |
| S | Carya. |
| P | Populus. |
| E | Ulmus. |

is open and free from vegetation. The north side and west end of the pond are occupied by button-bush. The edge is bordered by a zone of *Iris*. There is a zone of cattails (*Typha latifolia*) at the south side; the east end is shallow and is filled with swamp grass.

The following trees occupy the area surrounding the pond:

| | |
|---|---|
| *Quercus bicolor.* | Swamp White Oak. |
| *Cephalanthus occidentalis.* | Button-bush. |
| *Salix longifolia.* | River-bank Willow. |
| *Populus deltoides.* | Cottonwood. |
| *Populus tremuloides.* | Trembling Aspen. |
| *Ulmus americana.* | American Elm. |
| *Carya ovata.* | Shellbark Hickory. |

Animal life was fairly abundant, the invertebrates being as follows.

INSECTS.

| | |
|---|---|
| *Limnotrechus marginatus.* | Water-strider. |
| *Corixa interrupta.* | Water-boatman. |
| *Notonecta undulata.* | Back-swimmer. |
| *Zaitha fluminea.* | Water-bug. |
| *Tropisternus dorsalis.* | Water-beetle. |
| *Cybister* sp. | Larva of water-beetle. |
| *Sympetrum rubicundulum.* | Dragonfly (nymph). |
| *Libellula basalis.* | Dragonfly (adult). |
| *Anax junius.* | Dragonfly (nymph). |

MOLLUSKS.

FLUVIATILE SPECIES.

*Physa gyrina.* Abundant.
*Segmentina armigera.* Common.
*Lymnæa reflexa.* Rare.

LAND SPECIES.

*Succinea retusa.* Rare.

## Station XV.

(Plate XIV.)

An open area about thirty-five feet in diameter in the midst of a rather thick growth of trees. The ground is covered with dead leaves, dead branches and other forest debris.

The forest surrounding the area includes the following species:

| | |
|---|---|
| *Quercus bicolor.* | Swamp White Oak. |
| *Carya ovata.* | Shellbark Hickory. |
| *Ulmus americana.* | American Elm. |

Under the leaves and in cracks in the dry earth the following mollusks were found.

FLUVIATILE SPECIES.

*Sphærium occidentale.* Common.
*Physa gyrina.* Very rare.
*Aplexa hypnorum.* Common.
*Lymnæa caperata.* Rare.

LAND SPECIES.

*Succinea avara.* Rare.

During the spring this area is very wet, forming a miniature pond, a few inches in depth, but in the summer and fall it is dry and sun-baked.

## Station XVI.

(Plate XV.)

An oval depression on the highest portion of the intermediate ridge, about one hundred feet in longest diameter. The center of the pond is filled with cattails, about which is a zone of grass and aquatic plants. The pond is edged with bushes and bush-like trees, while the forest proper succeeds this formation. There are thus four different kinds of plant societies, or three zones surrounding a

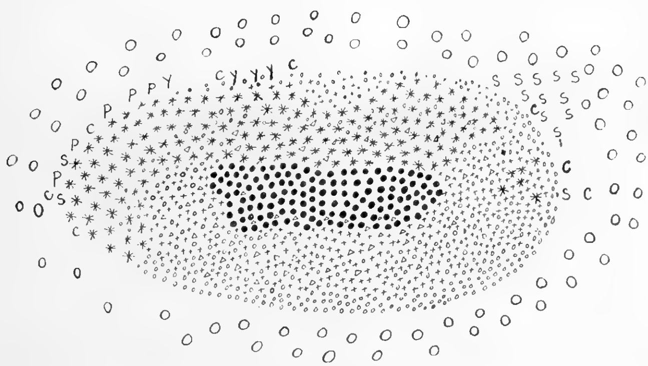


FIGURE 4.

Diagram showing relation of characteristic vegetation of Station XVI.

- * Cephalanthus occidentalis.
- ● Typha latifolia.
- o Iris versicolor.
- + Dulichium spathaceum.
- △ Sagittaria latifolia.
- O Quercus coccinea.
- S Quercus bicolor.
- Y Salix longifolia.
- P Populus tremuloides, Corylus, Hamamelis, Viburnum, etc.

central nucleus. (Fig. 4.) The plant societies may be tabulated as follows.

CENTRAL AREA.

| | |
|---|---|
| *Typha latifolia.* | Cattails. |

FIRST ZONE.

| | |
|---|---|
| *Sparganium eurycarpum.* | Broad-fruited Bur-Reed. |
| *Sagittaria latifolia.* | Broad-leaved Arrow-head. |
| *Iris versicolor.* | Large Blue Flag. |
| *Dulichium arundinaceum.* | Sedge. |

SECOND ZONE.

This zone is confined to the east, west and north sides. On the north side the button-bush has filled the pond to the *Typha* society.

| | |
|---|---|
| *Populus tremuloides.* | American Aspen. |
| *Cephalanthus occidentalis.* | Button-bush. |
| *Corylus americana.* | Hazelnut. |
| *Hamamelis virginiana.* | Witch Hazel. |
| *Viburnum lentago.* | Nanny-berry. |
| *Salix longifolia.* | River-bank Willow. |

THIRD ZONE.

| | |
|---|---|
| *Quercus bicolor.* | Swamp White Oak. |
| *Quercus coccinea.* | Scarlet Oak. |
| *Carya ovata.* | Shellbark Hickory. |
| *Ulmus americana.* | American Elm. |
| *Ostrya virginiana.* | Hop Hornbeam. |

In the late summer, the first zone becomes covered with small plants, ferns, etc., among which the following species are notable:

| | |
|---|---|
| *Viola blanda.* | Sweet White Violet. |
| *Fragaria virginiana.* | Scarlet Strawberry. |
| *Ranunculus multifidus.* | Yellow Water-Crowfoot. |
| *Onoclea sensibilis.* | Sensitive Fern. |
| *Aspidium thelypteris.* | Marsh Shield Fern. |
| *Aspidium cristatum.* | Crested Shield Fern. |

*Ranunculus multifidus* is abundant over the entire ponded area, both under water and forming a carpet on the dry border.

Insect life is abundant in the spring, but is rare in the fall owing to the almost complete drying-up of the pond. The following species were noted.

INSECTS.

| | |
|---|---|
| *Corixa interrupta.* | Water-boatman. |
| *Notonecta undulata.* | Back-swimmer. |
| *Zaitha fluminea.* | Water-bug. |
| *Limnotrechus marginatus.* | Water-strider. |

Mollusks were very abundant in this pond, especially the larger species. Only a few individuals of two or three species (*Musculium*, *Physa*, *Lymnæa*) were found in the central cattail area, the majority being found about the edges of the pond near the button-bushes, where they had taken refuge beneath the wet leaves and grass when the water disappeared. Under decaying logs and about the roots of the shrubs were the best localities for the majority of the species. The Lymnæas were abundant under damp vegetation at the east end of the pond (July–August). In this wet situation the Lymnæas, as well as some Physas and a few Musculiums, are able to survive the long dry summer and are ready to revive when the fall rains begin.

The following species of mollusks were secured in this pond.

FLUVIATILE SPECIES.

*Sphærium occidentale.* Not common.
*Musculium partumeium.* Common.
*Physa gyrina.* Common.
*Segmentina armigera.* Common.
*Planorbis exacuous.* Common.
*Lymnæa reflexa.* Common.

LAND SPECIES.

*Succinea avara.* Rare.

## Station XVII.

A small depression about 100 feet southwest of Station XVI, thirty feet or more in diameter. The arboreal vegetation in and about this spot is as follows.

| | |
|---|---|
| *Ostrya virginiana.* | Hop Hornbeam. |
| *Cephalanthus occidentalis.* | Button-bush. |
| *Quercus bicolor.* | Swamp White Oak. |
| *Carya ovata.* | Shellbark Hickory. |

In summer and autumn this locality is dry and becomes filled with dead leaves. Under these leaves the following bivalve mollusk may be found in large numbers:

*Sphærium occidentale.* Very common.

## Vertebrate Life; Stations VII—XVII.

The area included in Stations VII to XVII abounds in avian life, both during migration and in the summer months, the locality affording excellent nesting sites for the birds, a majority of which nest in the vicinity.

Vertebrates were observed as follows.

### LOWER VERTEBRATES.

The following species were found about the edges of the ponds and pools:

| | |
|---|---|
| *Rana pipiens.* | Leopard-frog. |
| *Amblystoma jeffersonianum.* | Jefferson's Salamander. |
| *Hemidactylium scutatum.* | Scaly or Four-toed Salamander. |

### BIRDS.

| | |
|---|---|
| American Bittern. | Nesting in reeds of Station VII. |
| Green Heron. | Nesting in oak tree on edge of Station VII. Young out of nest July 29. |
| Great Blue Heron. | |
| Sparrow Hawk. | |
| Red-shouldered Hawk. | |
| Red-tailed Hawk. | |
| Cooper's Hawk. | |
| Yellow-billed Cuckoo. | |
| Flicker. | |
| Red-headed Woodpecker. | |
| Downy Woodpecker. | |
| White-bellied Swallow. | |
| Whippoorwill. | |
| Nighthawk. | |
| Kingbird. | |
| Wood Pewee. | |
| Chickadee. | |
| Crow. | |
| Blue Jay. | |

| | |
|---|---|
| Red-winged Blackbird. | Nesting in Station VII. |
| Song Sparrow. | |
| Red-eyed Vireo. | |
| Warbling Vireo. | |
| American Redstart. | |
| Yellow Warbler. | |
| Ovenbird. | |
| Northern Yellow-throat. | |
| Catbird. | |
| Robin. | |
| Wood Thrush. | |
| Bluebird. | |

## Station XVIII.

(Plates XVI. and XVII.,1.)

An oval depression 80 by 125 feet in the edge of the woods east of the East Branch of the Chicago River, bordering an open field. In the spring this depression forms a large pond, two or more feet in depth, which supports a varied and abundant fauna. In the summer and fall the water evaporates, leaving an open space in the woods, with dry, mud-cracked surface which is covered with dead leaves. Aquatic vegetation (excepting algæ) is rare in this pond, only a few flags growing in a wet depression, subject to overflow from the larger body of water.

The characteristic vegetation is as follows.

In the Pond.

*Algæ.* Sp. undet.

Bordering the Pond.

| | |
|---|---|
| *Iris versicolor.* | Large Blue Flag. |
| *Cephalanthus occidentalis.* | Button-bush. |

In the Forest surrounding the Pond.

| | |
|---|---|
| *Quercus bicolor.* | Swamp White Oak. |
| *Quercus coccinea.* | Scarlet Oak. |
| *Ostrya virginiana.* | Hop Hornbeam. |

The insect and molluscan species thrive well among the thick clumps of algæ. The following species were secured.

MOLLUSKS.

FLUVIATILE SPECIES.

*Physa gyrina.* Very common.
*Lymnæa reflexa.* Rare.

LAND SPECIES.

*Agriolimax campestris.* Common.

The absence of *Sphæriidæ* is noteworthy.

INSECTS.

| | |
|---|---|
| *Hydroporus undulatus* | Diving Beetle. |
| *Dytiscus* sp. | Larva of water-beetle. |
| *Notonecta undulata.* | Back-swimmer. |
| *Corixa interrupta.* | Water-boatman. |
| *Limnotrechus marginatus.* | Water-strider. |
| *Leucorhinia* sp. | Dragonfly (nymph). |
| *Libellula basalis.* | Dragonfly (adult). |
| *Epiæschna heros.* | Dragonfly (nymph). |

CRUSTACEA.

*Cambarus blandingi acutus.* Crawfish.

## Station XIX.

An irregular depression, two hundred or more feet west of Station XVII, lying in a northeast by southwest direction. This area is about one hundred feet long by forty feet wide, and is well stocked with plant life, among which the following species are conspicuous:

| | |
|---|---|
| *Iris versicolor.* | Large Blue Flag. |
| *Sparganium eurycarpum.* | Broad-fruited Bur-Reed. |

The following species of trees surround the area:

| | |
|---|---|
| *Ostrya virginiana.* | Hop Hornbeam. |
| *Cratægus punctata.* | Large-fruited Thorn. |
| *Carya ovata.* | Shellbark Hickory. |
| *Quercus bicolor.* | Swamp White Oak. |
| *Cephalanthus occidentalis.* | Button-bush. |

During the spring this depression is filled with water to the depth of about eighteen inches. In the summer the water evaporates and the ground becomes hard and sun-baked. The mollusks bury themselves in the mud-cracks, and hide under leaves and in crawfish chimneys. The old stumps in and about this area afford shelter for several species of land mollusks.

The following species of Mollusca were secured.

FLUVIATILE SPECIES.

*Sphærium occidentale.* Common.
*Physa gyrina.* Rare.
*Lymnæa caperata.* Rare.

LAND SPECIES.

*Agriolimax campestris.* Common.
*Zonitoides arboreus.* Common.
*Strobilops virgo.* Rare.

The following were associated with the land mollusks.

BEETLES.

*Penthe obliquata;* adult.
*Meracantha contracta;* adult.
*Alobates pennsylvanicus;* adult.
*Anisodactylus baltimorensis;* adult.
*Scotobates calcaratus;* adult.
*Patrobus longicornis;* adult.
*Pterostichus scrutator;* adult.
*Alaus oculatus;* larva.

ORTHOPTERA.

*Ischnoptera* sp. Cockroach (nymph).

CRUSTACEA.

*Cambarus blandingi acutus.* Crawfish.

## Station XX.

A small pool east of Station XVIII, extending from the edge of the woods into the open field. The pool is shallow, irregular in shape and bordered by a few scattering trees from Station XVIII, among which the button-bush (*Cephalanthus occidentalis*) is conspicuous. It is dry in the summer and fall. *Physa gyrina* was the only animal observed, and this was very abundant.

## Vertebrates in the Vicinity of Stations XVII–XX.

In the triangular piece of woodland, between the river and the open field, including within its borders Stations XVIII to XX, a number of vertebrate animals were observed.

### REPTILIA.

A large garter-snake (*Eutænia sirtalis*) was observed nicely tucked away between a large piece of "started" bark and the stump of an old tree. It was discovered while pulling the bark away in a search for mollusks.

### AVES.

Birds were very plentiful in this area, and were as noted below:

American Bittern.
Great Blue Heron.
Green Heron.
Cuckoo; nesting.
Flicker; nesting.
Crow; nesting.
Bronzed Grackle.
Red-winged Blackbird.
Blue Jay.
Cowbird.
Swamp Sparrow.
White-throated Sparrow.
Bobolink; nesting.
Chewink.
Catbird; nesting.
Wood Thrush.
Brown Thrasher; nesting.
Robin.
Bluebird.

## C. EAST BRANCH OF THE CHICAGO RIVER.

(Stations XXI–XXIX.)

### Station XXI.

(Plates XVII.,2, and XVIII.,1.)

As previously intimated, in the spring the river is quite wide and contains an abundance of water (Plate XVII.,2), but in the fall (Plate XVIII.,1) is reduced to a succession of elongated pools into which the aquatic life crowds at this season of the year. The bottom of the river is composed of sticky blue clay. The whole area is much trodden by the feet of cattle.

The principal plant life of the river is as follows:

| | |
|---|---|
| *Polygonum pennsylvanicum* | Pennsylvania Persicaria. |
| *Polygonum hydropiperoides.* | Mild Water-Pepper. |
| *Iris versicolor.* | Large Blue Flag. |

The *Polygonum* forms large masses in the shallower portions of the river.

MOLLUSKS.

The molluscan fauna of the stream is quite varied, the mollusks being able to adapt themselves to the rigorous summer conditions, at which time they retreat to the small pools which are left in the deeper parts of the stream.

The appended list of species is large, considering the character of the habitat.

*Lampsilis parva.* Common.
*Anodonta grandis.* Common.
*Anodontoides ferussacianus.* Occasional.
*Sphærium stamineum.* Abundant.
*Musculium transversum.* Abundant.
*Physa gyrina.* Abundant.
*Ancylus rivularis.* Common.
*Planorbis trivolvis.* Abundant.
*Planorbis parvus.* Common.

The pelecypods thrive in the soft blue clay, the unionids in the deeper parts, the sphæriids along the shore in shallow water. *Ancylus rivularis* and *Planorbis parvus* live on the stems of rushes.

INSECTS.

The insect life of the river is apparently the same as that in the larger ponds and pools of the intermediate ridge. The following were observed:

| | |
|---|---|
| *Limnotrechus marginatus.* | Water-strider. |
| *Corixa interrupta.* | Water-boatman. |
| *Zaitha fluminea.* | Water-bug. |
| *Dineutes assimilis.* | Water-beetle. |
| *Notonecta undulata.* | Back-swimmer. |

VERTEBRATES.

The river vertebrates observed were as follows:

| | |
|---|---|
| *Rana pipiens.* | Leopard-frog. |
| *Chrysemys marginata.* | Western Painted Tortoise. |
| *Ameiurus melas.* | Black Bullhead. |

## Station XXII.

In many places the river forms bayous of considerable depth, which are largely filled with *Iris versicolor.* This area, as well as certain portions of the flood-plain adjacent to the river, is subject to overflow. *Physa* and *Planorbis* are abundant in this habitat, and *Lymnæa parva sterkii* is common on the margin on leaves and sticks, or on the bare surface of the mud. It is seldom found in the water.

MOLLUSKS.

*Physa gyrina.*
*Planorbis trivolvis.*
*Lymnæa parva sterkii.*

## Station XXIII.

Small streams running into river, on west bank. These streams start from springs in the higher ground and gradually enlarge until, in several cases, a stream has been formed two or three feet in width. That there is frequently a large volume of water is shown by the depth to which the stream has cut, forming a miniature valley, and cutting away a large portion of the surrounding area. In the summer and fall these streams completely dry up. The banks on the west side of the river are more heavily wooded, thereby holding the water and storing it up in springs.

*Physa gyrina* was the only mollusk found in these streams.

## Station XXIV.

(Plate XIX.)

The flood-plain between the river and the terrace-like banks. The ground is low and level, and subject more or less to overflow from the river during high water. The vegetation is made up of two main plant societies—(1) the trees which have descended from the terraced banks and (2) the more natural semiaquatic vegetation. The notable species of each group are as follows.

Vegetation characteristic of wet and swampy localities:

| | |
|---|---|
| *Cephalanthus occidentalis.* | Button-bush. |
| *Iris versicolor.* | Large Blue Flag. |
| *Verbena hastata.* | Blue Vervain. |
| *Lobelia cardinalis.* | Cardinal Flower. |
| *Penthorum sedoides.* | Ditch Stonecrop. |

Trees encroaching from higher ground:

| | |
|---|---|
| *Carya ovata.* | Hazelnut. |
| *Populus tremuloides.* | American Aspen. |
| *Ulmus americana.* | American Elm. |
| *Quercus bicolor.* | Swamp White Oak. |
| *Cratægus punctata.* | Large-fruited Thorn. |
| *Acer saccharum.* | Sugar or Rock Maple. |

Beneath decaying logs and under "started" bark, in depressions in the bark, in rotting stumps and in crevices, the smaller land mollusks, as well as insects, are more or less abundant.

MOLLUSKS.

| | |
|---|---|
| *Agriolimax campestris.* | Common. |
| *Zonitoides arboreus.* | Common. |
| *Vitrea indentata.* | Rare. |

INSECTS.

BEETLES.

*Ceruchus piceus.* Adult.
*Alaus oculatus.* Larva.

ORTHOPTERA.

*Ischnoptera intricata.* Adult.

LOWER VERTEBRATES.

| | |
|---|---|
| *Amblystoma jeffersonianum.* | Jefferson's Salamander. |
| *Rana pipiens.* | Leopard-frog. |

BIRDS.

The avian life was abundant, the following species being noted:

American Bittern.
Great Blue Heron.
Green Heron; nesting.
American Osprey.

Belted Kingfisher.
Yellow-billed Cuckoo.
Hairy Woodpecker; nesting.
Northern Flicker.
Nighthawk.
Long-billed Marsh Wren.
Blue Jay.
American Crow; nesting.
Red-winged Blackbird.
Swamp Sparrow.
Phœbe.
Song Sparrow.
Yellow Warbler.
Northern Yellow-throat.
Catbird.

### Station XXV.

A small depression about eight feet in diameter, a few feet from the river, north of the Glencoe road. In the spring this spot is filled with water which overflows into the river, but in the summer and fall it becomes perfectly dry. It is bordered on the one side, near the road, by a number of *Cratægus* bushes (*C. punctata*), and on the other side by an open field.

It is noteworthy that the mollusks are the same as those in the smaller summer-dry ponds mentioned previously. The *Lymnæa* is not found in the river. The *Lymnæa* is the most abundant, the *Physa* being represented by only a few individuals.

*Physa gyrina.*
*Lymnæa caperata.*

### Station XXVI.

(Plate XX.)

A rather large area (several acres) of virgin forest, situated north of the Glencoe road and west of the middle branch of the river. The vegetation consists of the following trees, which are of large size:

| | |
|---|---|
| *Quercus bicolor.* | Swamp White Oak. |
| *Ulmus americana.* | American Elm. |
| *Carya ovata.* | Shellbark Hickory. |
| *Corylus americana.* | Hazelnut. |
| *Tilia americana.* | Basswood. |
| *Cratægus punctata.* | Large-fruited Thorn. |

Beneath the trees the vegetation consists of bushes and ground plants, among which the following are conspicuous:

| | |
|---|---|
| *Sium cicutæfolium.* | Hemlock Water-Parsnip. |
| *Rudbeckia laciniata.* | Green-headed Coneflower. |
| *Cicuta maculata.* | Water Hemlock. |
| *Campanula americana.* | Tall Bellflower. |
| *Trillium* sp. | Wake-robin. |
| *Arisæma triphyllum.* | Jack-in-the-pulpit. |
| *Viola palmata.* | Early Blue Violet. |

A small brook flows through this forest, and empties into the East Branch of the Chicago River. The banks of the brook are low, from six inches to a foot above the water, and are thickly lined with low-growing plants and flowers.

*Lymnæa caperata* is apparently the only mollusk which inhabits this brook.

## Station XXVII.

Small pools in depressions caused by heavy rains. These pools overflow into the brook mentioned under Station XXVI. The only life observed in these pools was a mollusk (*Aplexa hypnorum*) and a leech. The mollusks were observed crawling over the dead leaves on the bottom of the pool or swimming, shell downward, on the surface of the water. The leech was found on the surface of the leaves.

## Station XXVIII.

(Plate XXI.)

The whole area of Station XXVI is covered with old stumps and logs, all half rotten, with the bark "started" and on many logs partly peeled off. There is also an abundance of the usual forest debris of small sticks, leaf mold, fallen trees, etc. In the spring these half-decayed relics are partly hidden by the long grass, vines and flowers which abound in this area. The logs and stumps are further ornamented by huge fungus growths. Life is very abundant in this station. The following species were noted.

### MOLLUSKS.

| | |
|---|---|
| *Pyramidula alternata.* | Found under old logs and crawling over the surface of the ground. |
| *Polygyra thyroides.* | |

| | |
|---|---|
| *Succinea avara.* | On old logs, sticks, etc., above the water. |
| *Vitrea hammonis.*<br>*Vitrea indentata.*<br>*Helicodiscus parallelus.*<br>*Vertigo ovata.*<br>*Carychium exile.*<br>*Zonitoides arboreus.* | On old logs, in crevices and under "started" bark; also in moss. |
| *Euconulus fulvus.* | On rather dry bark on ground. |
| *Agriolimax campestris.* | On wet bark and leaves; in dry weather under "started" bark and under logs. |

INSECTS.

Insects were not abundant in species, but individuals were numerous of the few species observed. These were secured under bark of rotting logs.

BEETLES.

*Penthe obliquata.* Adult.
*Copris anaglypticus.* Adult.
*Elater* sp. Larva.

MYRIAPODA.

*Lithobius* sp. Centipede.

BIRDS.

The following summer-resident birds were observed at this station:

| | |
|---|---|
| American Woodcock. | Nesting. |
| Red-shouldered Hawk. | Nesting. |
| American Sparrow Hawk. | Nesting. |
| Screech Owl. | Nesting. |
| Yellow-billed Cuckoo. | Nesting. |
| Downy Woodpecker. | |
| Northern Flicker. | |
| Nighthawk. | |
| Crested Flycatcher. | |
| Wood Pewee. | |
| Phœbe. | |
| Blue Jay. | |
| American Crow. | |
| Cowbird. | |
| American Goldfinch. | |

Song Sparrow.
Rose-breasted Grosbeak.
Indigo Bird.
Scarlet Tanager.
Tree Swallow.
Red-eyed Vireo.
Cerulean Warbler.
Ovenbird.
Yellow-breasted Chat.
American Redstart.
Catbird.
Brown Thrasher. Nesting.
White-breasted Nuthatch.
Chickadee.
Wood Thrush.
American Robin.

### Station XXIX.

A wide ditch beside road near Station XXVII. The water was stagnant and the animal life consisted of one mollusk (*Physa gyrina*) and a leopard-frog (*Rana pipiens*).

## D. GLENWOOD BEACH RIDGE.

(Stations XXX–XXXIV.)

### Station XXX.

Heavy woods on west bank of East Branch of the Chicago River. The surface rises somewhat abruptly at first and then becomes level. The area is rather heavily timbered and the ground is covered with a large amount of forest debris. In the early spring the ground is almost carpeted with flowers such as the early blue violet (*Viola palmata*).

The principal forest trees are as follows:

| | |
|---|---|
| *Quercus bicolor.* | Swamp White Oak. |
| *Ulmus americana.* | American Elm. |
| *Carya ovata.* | Shellbark Hickory. |
| *Ostrya virginiana.* | Hop Hornbeam. |
| *Populus tremuloides.* | American Aspen. |
| *Acer saccharum.* | Sugar or Rock Maple. |

The following mollusks were observed:

*Philomycus carolinensis*. Common.
*Polygyra albolabris*. Rare.
*Polygyra thyroides*. Common.
*Zonitoides arboreus*. Common.
*Vitrea hammonis*. Common.
*Helicodiscus parallelus*. Rare.

*Philomycus* lives under large logs, as do also the Polygyras. The small helices are abundant under "started" bark. All of the *Polygyra thyroides* were dentate.

VERTEBRATES.

Avian life was very abundant in this station and the following species were noted:

| | |
|---|---|
| Red-shouldered Hawk. | Nesting. |
| Screech Owl. | |
| Yellow-billed Cuckoo. | Nesting. |
| Red-headed Woodpecker. | |
| Northern Flicker. | |
| Nighthawk. | |
| Crested Flycatcher. | |
| Wood Pewee. | |
| Blue Jay. | |
| American Crow. | Nesting. |
| Cowbird. | |
| American Goldfinch. | Nesting. |
| Indigo Bunting. | Nesting. |
| Towhee. | |
| Rose-breasted Grosbeak. | |
| Scarlet Tanager. | |
| Chipping Sparrow. | |
| Yellow Warbler. | Nesting. |
| Ovenbird. | |
| Catbird. | Nesting. |
| Wood Thrush. | Nesting. |
| Brown Thrasher. | Nesting. |
| American Robin. | Nesting. |

## Station XXXI.

A small pool about a quarter of a mile from the river, and apparently the head of one of the streams flowing into the river in the spring. The small depression is choked up with dead leaves in the summer and fall. Under these leaves *Aplexa hypnorum* is very abundant. The bordering vegetation is the same as that surrounding the pools mentioned under Station XXXII.

The following mollusks were observed:

*Aplexa hypnorum.* Common.
*Succinea avara.* Rare.

## Station XXXII.

(Plates XXII., XXIII., and XXIV.,1.)

A pond about three hundred by one hundred feet, situated on the edge of a rather dense forest of American elm, shellbark hickory and swamp white oak trees. The pond is bordered on the north by the heavy forest, on the east by the open forest, on the west by a steep ridge and on the south by an open field. Unlike the ponds previously considered, the aquatic vegetation is scant and confined to a few scattering Iris at the north end. The bottom of the pond is composed of sticky blue clay. The pond is very interesting, lying, as it does, at the very base of the steep ridge and differing so markedly from the other ponds of this region in the almost total absence of cattails (*Typha*) and other reeds. Plate XXII. shows its location at the base of the ridge and Plate XXIV., 1, shows its condition in September after a prolonged period of drouth. In the early spring, the water extends to the trunks of the trees, as shown in Plate XXIII., which was, however, photographed in September, 1909. Comparison between this plate and Plate XXIV., 1, will illustrate the effect of a dry and a wet season on the ponds and pools in this area.

Only a few species of mollusks were observed in the pond.

At the north end, under wet leaves, in a low area subject to inundation, *Ancylus parallelus* was found in considerable numbers attached to the under surface of the dead leaves.

The following species of trees were noted about the pond:

| | |
|---|---|
| *Carya ovata.* | Shellbark Hickory. |
| *Populus tremuloides.* | American Aspen. |
| *Quercus bicolor.* | Swamp White Oak. |
| *Quercus rubra.* | Red Oak. |
| *Ulmus americana.* | American Elm. |
| *Tilia americana.* | American Basswood. |
| *Acer saccharum.* | Rock Maple. |
| *Salix longifolia.* | River-bank Willow (in pond). |

Vegetation at the north end:

| | |
|---|---|
| *Iris versicolor.* | Great Blue Flag. |
| *Cephalanthus occidentalis.* | Button-bush. |

MOLLUSKS.

*Musculium partumeium.* Common.
*Planorbis trivolvis.* Common.
*Ancylus parallelus.* Common.
*Segmentina armigera.* Common.

INSECTS IN POND.

| | |
|---|---|
| *Hydroporus undulatus.* | Water-beetle. |
| *Graphoderes liberus.* | Water-beetle. |

LOWER VERTEBRATES.

The only aquatic vertebrate seen was the Western Painted Tortoise (*Chrysemys marginata*), which was very abundant.

AVES.

The following birds were observed about the pond.

Green Heron.
Kingfisher.
Red-headed Woodpecker.
Flicker.
Crow.

## Station XXXIII.

A large area in the woods, about four hundred feet north of Station XXXII, subject to periodic inundation. The area covered, appears to be two hundred feet long and thirty or more feet wide. The forest is quite dense, and is composed of the same kinds of trees as those recorded for Station XXXII. The wet area is sparsely covered with tall grass and reeds and other water-loving plants.

Among others, the following are conspicuous:

| | |
|---|---|
| *Iris versicolor.* | Large Blue Flag. |
| *Cephalanthus occidentalis.* | Button-bush. |
| *Sparganium eurycarpum.* | Broad-fruited Bur-Reed. |

The mollusks noted below were observed:

*Planorbis trivolvis.* Rare.
*Succinea avara.* Common.
*Polygyra albolabris.* A few observed under logs.

The absence of *Lymnæa caperata* as well as of *Sphærium occidentale* and *Musculium* is noteworthy.

## Station XXXIV.

(Plate XXIV., 2.)

Open fields and meadows north of the Shermerville road and west of the East Branch of the Chicago River, on rather high ground. The fields are allowed to grow grass for hay. The meadow clover (*Trifolium pratense*) is the most conspicuous plant, with the addition of the buttercup (*Ranunculus acris*) in the spring. In many places in these fields and meadows there is an abundance of old pieces of wood, small pieces of board fences, rotting stumps and other debris, under which the smaller land mollusks abound.

This station yielded the following species.

MOLLUSKS.

*Agriolimax campestris.*
*Bifidaria contracta.*
*Bifidaria pentodon.*
*Euconulus fulvus.*
*Strobilops virgo.*
*Zonitoides arboreus.*

Several species of beetles and a myriapod were found associated with the mollusks, as follows.

BEETLES.

*Coccinella* 9-*notata.*
*Platynus punctiformis.*
*Euphoria inda.*

MYRIAPODA.

*Lithobius* sp. Centipede.

BIRDS.

The birds noted below were observed in and about the fields:

Red-headed Woodpecker.
Northern Flicker.
Chimney Swift.
Kingbird.
Blue Jay.

Bobolink; nesting.
Meadowlark; nesting.
Bronzed Grackle.
Field Sparrow; nesting.
Song Sparrow.
Barn Swallow.
Brown Thrasher; nesting in *Cratægus* bush near road.
American Robin.

## E. NORTH BRANCH OF THE CHICAGO RIVER.

(Stations XXXV, XXXVI.)

### Station XXXV.

Swampy, ditch-like overflow (from the river) on east side of railroad embankment, north of Shermerville. The water is shallow and stagnant for the most part. *Iris versicolor* was the conspicuous plant.

Three species of mollusks were abundant:

*Physa gyrina.*
*Planorbis trivolvis.*
*Lymnæa caperata.*

### Station XXXVI.

(Plate XVIII.,2.)

The river. No opportunity presented itself for examining the bed of this river for pelecypods. It is used for sewage purposes, and is, therefore, a difficult stream to study.

Two species of fresh-water pulmonates were observed in abundance:

*Physa gyrina.*
*Planorbis trivolvis.*

### Summary.

A study of the two appended tables reveals some interesting facts. In Table I (terrestrial species), Station XXVIII yields the largest number of species (11), and Station V follows with eight species. These habitats are the heavy woods where there is an abundance of forest debris. The Succineas are present in the majority of stations, *retusa* and *avara* being most frequently seen. The small zonitoids, the pupoids and *Philomycus* seem to be the least widely distributed in this limited area. The last was observed in but one habitat.

The typical molluscan societies and their habitat relations may be summed up as follows.

In swamp with *Typha* or *Iris*.

*Succinea retusa*, *Succinea avara*, *Agriolimax campestris*.

On low ground subject to overflow.

*Agriolimax campestris*, *Polygyra thyroides*, *Polygyra fraterna*, *Pyramidula alternata*, *Zonitoides arboreus*, *Vitrea hammonis*.

On higher grounds, raised above overflow.

*Succinea ovalis*, *Agriolimax campestris*, *Polygyra albolabris*, *Philomycus carolinensis*.

On dry ground.

*Strobilops virgo*, *Helicodiscus parallelus*, *Vitrea indentata*, *Euconulus fulvus*, *Bifidaria contracta*, *B. pentodon*.

Living under "started" bark, etc.

*Zonitoides*, *Vitrea*, *Strobilops*, *Helicodiscus*, *Vertigo*, *Euconulus*, *Bifidaria* and *Carychium*. *Pyramidula* is frequently found under "started" bark, and *Polygyra albolabris* haunts holes and large crevices in dry weather.

Table II (fluviatile species) is also of interest. Station XXI, the East Branch of the Chicago River, yields nine species. The highest number of species from any other habitat is seven, which number was observed in Stations IV and XI. Both are summer-dry ponds. *Physa gyrina* is the most abundant species, occurring in all but six of the fluviatile habitats. The naiads are the least abundant, occurring only in the East Branch of the Chicago River.

The habitat relations of the molluscan societies may be summarized as follows.

Found in all varieties of habitat.

*Physa gyrina*.

In large summer-dry ponds.

*Physa gyrina, Planorbis trivolvis, Planorbis parvus, Planorbis exacuous, Segmentina armigera, Musculium partumeium, Ancylus parallelus, Lymnæa reflexa.*

In small pools of very transient character.

*Lymnæa caperata, Aplexa hypnorum, Sphærium occidentale.*

In the river, which does not run dry.

*Sphærium stamineum, Musculium transversum, Lampsilis, Anodonta, Anodontoides, Physa gyrina, Planorbis trivolvis, Ancylus rivularis.*

Semiaquatic; on the edges of river and pools.

*Lymnæa parva sterkii.*

In brooks and overflow from river.

*Lymnæa caperata.*

TABLE I. TERRESTRIAL SPECIES.

| | STATION NUMBER | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | II | III | IV | V | VII | VIII | IX | X | XII | XIV | XV | XVI | XVII | XIX | XXIV | XXVIII | XXX | XXXI | XXXIII | XXXIV |
| Carychium exile | | | | | | | | | | | | | | | | * | | | | |
| Vertigo ovata | | | | | | | | | | | | | | | | * | | | | |
| Bifidaria contracta | | | | | | | | | | | | | | | | | | | | * |
| Bifidaria pentodon | | | | | | | | | | | | | | | | | | | | * |
| Strobilops virgo | | | | | | | | | | | | | | * | | | | | | * |
| Succinea avara | * | * | * | * | | * | | | * | | * | * | | | | * | | * | * | |
| Succinea retusa | * | * | * | | * | | * | * | * | * | | | | | | | | | | |
| Succinea ovalis | | | | | | * | | | * | | | | | | | | | | | |
| Succinea ovalis optima | | | | * | | | | | | | | | | | | | | | | |
| Philomycus carolinensis | | | | | | | | | | | | | | | | | * | | | |
| Pyramidula alternata | | | | * | | * | | | | | | | | | | * | | | | |
| Helicodiscus parallelus | | | | | | | | | | | | | | | | * | * | | | |
| Agriolimax campestris | * | | | | | * | * | | | | | | * | * | * | * | | | | * |
| Zonitoides arboreus | | | | * | | * | | | | | | | | * | * | * | * | | | * |
| Euconulus fulvus | | | | | | | | | | | | | | | | * | | | | * |
| Vitrea hammonis | | | | * | | | | | | | | | | | | * | * | | | |
| Vitrea indentata | | | | | | | | | | | | | | | * | * | | | | |
| Polygyra albolabris | | | | * | | * | | | | | | | | | | | * | | * | |
| Polygyra thyroides | | | | * | | | | | * | | | | | | | * | * | | | |
| Polygyra fraterna | | | | * | | * | | | * | | | | | | | | | | | |
| Total of Species | 3 | 2 | 2 | 8 | 1 | 7 | 2 | 1 | 5 | 1 | 1 | 1 | 1 | 3 | 3 | 11 | 6 | 1 | 2 | 6 |

TABLE II. Fluviatile Species.

| | STATION NUMBER | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | I | II | III | IV | VI | VII | IX | X | XI | XIII | XIV | XV | XVI | XVII | XVIII | XIX | XX | XXI | XXII | XXIII | XXV | XXVI | XXVII | XXIX | XXXI | XXXII | XXXIII | XXXV | XXXVI |
| Physa gyrina | * | * | * | * | * | * | * | * | * | | * | * | * | | * | * | * | * | * | * | * | | | * | | | | * | * |
| Aplexa hypnorum | | | | * | | | | | * | * | | * | | | | | | | | | | | * | | * | | | | |
| Planorbis trivolvis | * | | * | | * | * | * | | | | | | | | | | | * | * | | | | | | | * | * | * | * |
| Planorbis parvus | | | | * | | | | | | | | | | | | | | * | | | | | | | | | | | |
| Planorbis exacuous | | | | | | | | | | * | | | * | | | | | | | | | | | | | | | | |
| Segmentina armigera | * | | * | * | | * | * | * | * | | * | | * | | | | | | | | | | | | | * | | | |
| Lymnæa reflexa | * | * | * | | | * | * | | * | | * | | * | | * | | | | | | | | | | | | | | |
| Lymnæa caperata | | | | * | | | | | * | * | | * | | | | * | | | | | * | * | | | | | | * | |
| Lymnæa parva sterkii | | | | * | | | | | | | | | | | | | | | * | | | | | | | | | | |
| Musculium partumeium | * | | * | | | * | * | * | * | | | | * | | | | | | | | | | | | | * | | | |
| Musculium transversum | | | | | | | | | | | | | | | | | | * | | | | | | | | | | | |
| Sphærium occidentale | | | | * | | | * | | * | * | | * | * | * | | * | | | | | | | | | | | | | |
| Sphærium stamineum | | | | | | | | | | | | | | | | | | * | | | | | | | | | | | |
| Lampsilis parva | | | | | | | | | | | | | | | | | | * | | | | | | | | | | | |
| Anodonta grandis | | | | | | | | | | | | | | | | | | * | | | | | | | | | | | |
| Anodontoides ferussacianus | | | | | | | | | | | | | | | | | | * | | | | | | | | | | | |
| Ancylus parallelus | | | | | | | | | | | | | | | | | | | | | | | | | | * | | | |
| Ancylus rivularis | | | | | | | | | | | | | | | | | | * | | | | | | | | | | | |
| Total of Species | 5 | 2 | 5 | 7 | 2 | 5 | 6 | 3 | 7 | 4 | 3 | 4 | 6 | 1 | 2 | 3 | 1 | 9 | 3 | 1 | 2 | 1 | 1 | 1 | 1 | 4 | 1 | 3 | 2 |

## Taxonomy.

It has been urged by some taxonomists that the ecological study of nature has no bearing upon the subject of taxonomy, and that little, if any, aid can be secured from this subject in unraveling the mysteries of specific differences. This opinion, however, does not appear to be based on the facts which have been gathered from this source. On the contrary, the study of ecology has proven an aid of great value in drawing specific and varietal lines and in ascertaining the true character and value of taxonomic characters; and it is quite logical that this should be the case, because the environment reacts upon the organism, causing the latter to be modified to fit the environmental conditions. This is especially true of fresh-water mollusks, which respond to every change of habitat.

Two interesting facts bearing upon the taxonomy of the fresh-water pulmonates have been discovered during the field work in connection with the present study. In 1821 Thomas Say described a large, long-spired *Physa* as *Physa gyrina* (Pl. XXV, Fig. 9–13). In 1866, G. W. Tryon described a small, short-spired *Physa* as *Physa oleacea* (Pl. XXV, Fig. 14–17). It was noted as the field work progressed, that these two species were always associated, and the fact soon became apparent that one was but the immature stage of the other, or, in other words, that *oleacea* was the half-grown shell of *gyrina*. To confirm this theory, a large *gyrina* was broken down until it became a perfect *oleacea*. *Gyrina* has five whorls, while *oleacea* has a trifle more than four. The evidence seems conclusive.

A *Lymnæa* attaining the size of an inch or more, lives in the intermittent or summer-dry ponds. It has been called both *Lymnæa palustris* and *Lymnæa reflexa*. It differs from *palustris* in having a narrower shell, and it is notable for developing within the outer lip a heavy rib or varix. It also appears to live exclusively in this type of habitat, the heavy varices being caused by the periodic formation of an epiphragm during the time when the pond is dry. As many as three of these may be found in a year. This habitat indicates that the age of the Lymnæas (as well as of certain Physas which inhabit such an environment) can not be ascertained by the number of these varices on the shell. These varices have been observed in a young shell six or seven millimeters in length, and as many as six of them have been counted on a shell thirty millimeters in length. It is believed that the formation of these varices is due to the exigencies of the habitat. The following interesting conclusion has gradually been reached as the studies on these Lymnæas progressed: the smallest, narrow forms with acute spire are *Lymnæa palustris michiganensis* Walker (Pl. XXV; Fig. 8); the larger form with more rounded whorls is *Lymnæa reflexa crystalensis* Baker (Pl. XXV, Fig. 2–3); and the fully mature form is *Lymnæa reflexa* Say (Pl. XXV, Fig. 1). In this instance a study of the ecological relations of the Mollusca in the area in question has shown the relationship of these three forms,—a relation which probably would not be discovered from a few isolated specimens in the study. It is also probable that Pilsbry's *Succinea ovalis optima* is the old or senile stage of *ovalis* (see Pl. XXV, Fig. 18–20).

To aid those ecologists who are not intimately acquainted with the mollusks and who may desire to use this class of animals in their field work, a systematic catalog of the Mollusca of the area is appended. Descriptions and figures of the majority of the species of mollusks which live in northeastern Illinois will be found in the writer's monograph of the "Mollusks of the Chicago Area,"* and a reference to plate and figure in that work is made for most of the species herein recorded.

This catalog includes two classes, three orders, fourteen families, twenty-three genera and thirty-eight species and varieties, all living within an area three miles long and one half mile wide.

* Bull. Nat. Hist. Surv. Chi. Acad. Sci., No. III.

# SYSTEMATIC CATALOG OF THE MOLLUSCA.

## Class PELECYPODA.

## Order PRIONODESMACEA.

### Superfamily Naiadacea.

### Family UNIONIDÆ.

#### Genus Lampsilis Rafinesque.

*Lampsilis parva* (Barnes). Moll. Chi. Area, Pl. XIII, Fig. 3, Station XXI.

#### Genus Anodonta (Bruguière) Lamarck.

*Anodonta grandis* Say. Moll. Chi. Area, Pl. II.
Station XXI. The shells of *grandis* are unusually thick and solid and of a rich greenish-brown color.

#### Genus Anodontoides Simpson.

*Anodontoides ferussacianus* (Lea). Moll. Chi. Area, Pl. V, Fig. 2. Station XXI.

## Order TELEODESMACEA.

### Superfamily Cyrenacea.

### Family SPHÆRIIDÆ.

#### Genus Sphærium Scopoli.

*Sphærium stamineum* Conrad. Moll. Chi. Area, Pl. XXVII, Fig. 1. Station XXI.

*Sphærium occidentale* Prime. Moll. Chi. Area, Pl. XXVII, Fig. 10.
Stations IV, IX, XI, XIII, XV, XVI, XVII, XIX. *Occidentale* is almost always, at least in the area under consideration, an inhabitant of transient pools and ditches.

#### Genus Musculium Link.

*Musculium partumeium* (Say). Moll. Chi. Area, Pl. XXVII, Fig. 6.
Stations I, III, VII, IX, X, XI, XVI, XXXII. The young of *partumeium* somewhat resemble immature *Musculium truncatum.* This species (*partumeium*) is quite characteristic of the summer-dry pools of northern Illinois.

*Musculium transversum* (Linsley). Moll. Chi. Area, Pl. XXVII, Fig. 5.
Station XXI. *Transversum* is characteristic of the rivers, which do not entirely dry up in the summer. It is never found, in this area in the summer-dry ponds.

# Class GASTROPODA.

## Subclass Euthyneura.

## Order PULMONATA.

## Suborder BASOMMATOPHORA.

### Superfamily Hygrophila.

### Family PHYSIDÆ.

#### Genus Physa Draparnaud.

*Physa gyrina* Say. Pl. XXV, Fig. 9–17.
Stations I, II, III, IV, VI, VII, IX, X, XI, XIV, XV, XVI, XVIII, XIX, XX, XXI, XXII, XXIII, XXV, XXIX, XXXV, XXXVI. *Physa gyrina* is characteristic of nearly all the aquatic habitats of the area. A study of the material, collected at different seasons, between April and November, shows that two species have been founded on age variation. The smaller forms (Pl. XXV, Fig. 14–17) are Tryon's *oleacea* and are immature. The larger forms (Pl. XXV, Fig. 9–13) are mature and represent Say's *gyrina*. The figures illustrate well the degree of elongation of the spire as the shell matures. The two forms were always found associated together. This discovery illustrates the value of ecological studies.

#### Genus Aplexa Fleming.

*Aplexa hypnorum* (Linné). Moll. Chi. Area, Pl. XXXII, Fig. 16.
Stations IV, XI, XIII, XV, XXVII, XXXI. *Hypnorum* is usually found in transient ponds or pools, associated with *Lymnæa caperata* and *Sphærium occidentale*.

### Family LYMNÆIDÆ.

#### Subfamily LYMNÆINÆ.

#### Genus Lymnæa Lamarck.

#### Subgenus *Galba* Schrank.

*Lymnæa caperata* Say. Moll. Chi. Area, Pl. XXX, Fig. 18.
Stations IV, XI, XIII, XV, XIX, XXV, XXVI, XXXV.

*Lymnæa parva sterkii* Baker. Pl. XXV, Fig. 21.
Stations IV, XXII.

#### Subgenus *Stagnicola* Leach.

*Lymnæa reflexa* Say. Pl. XXV, Fig. 1–8.
Stations I, II, III, VII, IX, XI, XIV, XVI, XVIII. The study of this species has revealed some very interesting results. Three forms of

Lymnæas have been described which at first sight appear quite distinct. These are *Lymnæa reflexa* Say, *Lymnæa reflexa crystalensis* Baker, and *Lymnæa palustris michiganensis* Walker. The summer-dry ponds studied yield all three forms, and it is at once apparent that they represent age variation only, *michiganensis* being quite immature (figures 7–8), *crystalensis* being three-quarters grown (figures 2–3), and *reflexa* representing the fully mature mollusk (figure 1). The Oregon and Washington forms cited by Walker (Nautilus, VI, p. 33) are probably the young of *Lymnæa proxima rowellii*, with which *reflexa* has been confused by western conchologists. The figures on the plate indicate the age variation.

### Family PLANORBIDÆ.

#### Genus Planorbis Müller.

#### Subgenus *Helisoma* Swainson.

*Planorbis trivolvis* Say. Moll. Chi. Area, Pl. XXXII, Fig. 7–10.
Stations I, III, VI, VII, IX, XXI, XXII, XXXII, XXXIII, XXXV, XXXVI.

#### Subgenus *Hippeutis* Agassiz.

*Planorbis exacuous* Say. Moll. Chi. Area, Pl. XXVI, Fig. 5.
Stations XIII, XVI.

#### Subgenus *Gyraulus* Agassiz.

*Planorbis parvus* Say. Moll. Chi. Area, Pl. XXVI, Fig. 7.
Stations IV, XXI.

#### Genus Segmentina Fleming.

#### Subgenus *Planorbula* Haldeman.

*Segmentina armigera* (Say). Moll. Chi. Area, Pl. XXX, Fig. 32.
Stations I, III, IV, VII, IX, X, XI, XIV, XVI, XXXII.

### Family ANCYLIDÆ.

#### Genus Ancylus Geoffroy.

#### Subgenus *Ferrissia* Walker.

*Ancylus rivularis* Say. Moll. Chi. Area, Pl. XXX, Fig. 29.
Station XXI.

*Ancylus parallelus* Haldeman. Pl. XXV, Fig. 22.
Station XXXII.

### Superfamily Akteophila.

### Family AURICULIDÆ.

### Genus Carychium Müller.

*Carychium exile* H. C. Lea. Moll. Chi. Area, Pl. XXVI, Fig. 4.
Station XXVIII.

## Suborder STYLOMMATOPHORA.

## MONOTREMATA.

### ORTHURETHRA.

### Family PUPILLIDÆ.

### Genus Vertigo Draparnaud.

*Vertigo ovata* Say. Moll. Chi. Area, Pl. XXX, Fig. 13.
Station XXVIII.

### Genus Bifidaria Sterki.

*Bifidaria contracta* (Say). Moll. Chi. Area, Pl. XXX, Fig. 8.
Station XXXIV.

*Bifidaria pentodon* (Say). Moll. Chi. Area, Pl. XXX, Fig. 12.
Station XXXIV.

### Genus Strobilops Pilsbry.

*Strobilops virgo* (Pilsbry). Pl. XXV, Fig. 23.
Stations XIX, XXXIV.

### HETERURETHRA.

### Superfamily Elasmognatha.

### Family SUCCINEIDÆ.

### Genus Succinea Draparnaud.

*Succinea avara* Say. Moll. Chi. Area, Pl. XXX, Fig. 25.
Stations II, III, IV, V, VIII, XII, XV, XVI, XXVIII, XXXI, XXXIII.

*Succinea retusa* Lea. Moll. Chi. Area, Pl. XXX, Fig. 24.
Stations II, III, IV, VII, IX, X, XII, XIV.

*Succinea ovalis* Say. Moll. Chi. Area, Pl. XXX, Fig. 22.
Stations VIII, XII. Quite typical, with broad aperture and greenish colored epidermis.

*Succinea ovalis optima* Pilsbry. Pl. XXV, Fig. 18–20.
Station V. The large form so abundant in Station V, appears to be Pilsbry's *optima*, the large individuals of which are quite characteristic; the smaller specimens approach very closely to typical *ovalis*, having the peculiar greenish color. Specimens from this region would seem to indicate that *optima* is the senile stage of *ovalis*.

## SIGMURETHRA.

### Superfamily AULACOPODA.

### Family PHILOMYCIDÆ.

#### Genus PHILOMYCUS (Rafinesque) Ferussac.

*Philomycus carolinensis* (Bosc.). Moll. Chi. Area, Pl. XXX, Fig. 1.
Station XXX.

### Family ENDODONTIDÆ.

#### Subfamily ENDODONTINÆ.

#### Genus PYRAMIDULA Fitzinger.

#### Subgenus *Patula* Haldeman.

*Pyramidula alternata* (Say). Moll. Chi. Area, Pl. XXVIII, Fig. 23–24.
Stations V, VIII, XXVIII.

#### Genus HELICODISCUS Morse.

*Helicodiscus parallelus* (Say). Moll. Chi. Area, Pl. XXVIII, Fig. 25.
Stations XXVIII, XXX.

### Family LIMACIDÆ.

#### Genus AGRIOLIMAX Mörch.

*Agriolimax campestris* (Say). Moll. Chi. Area, Pl. XXVIII, Fig. 13.
Stations II, VIII, IX, XVIII, XIX, XXIV, XXVIII, XXXIV.

### Family ZONITIDÆ.

#### Subfamily ARIOPHANTINÆ.

#### Genus ZONITOIDES Lehmann.

*Zonitoides arboreus* (Say). Moll. Chi. Area, Pl. XXVIII, Fig. 9.
Stations V, VIII, XIX, XXIV, XXVIII, XXX, XXXIV.

### Subfamily **ZONITINÆ.**

Genus Euconulus Reinhardt.

*Euconulus fulvus* (Müller). Moll. Chi. Area, Pl. XXVIII, Fig. 17.
Stations XXVIII, XXXIV.

Genus Vitrea Fitzinger.

*Vitrea hammonis* (Ström). Moll. Chi. Area, Pl. XXVIII, Fig. 10.
Stations V, XXVIII, XXX.

*Vitrea indentata* (Say). Moll. Chi. Area, Pl. XXVIII, Fig. 11.
Stations XXIV, XXVIII.

## Superfamily Holopoda.

## Family HELICIDÆ.

### Subfamily **POLYGYRINÆ.**

Genus Polygyra (Say) Pilsbry.

Section *Triodopsis* Rafinesque.

*Polygyra albolabris* (Say). Moll. Chi. Area, Pl. XXIX, Fig. 6
Stations V, VIII, XXX, XXXIII.

*Polygyra thyroides* (Say). Moll. Chi. Area, Pl. XXIX, Fig. 2.
Stations V, XII, XXVIII, XXX. About half of the adult specimens have the parietal tooth more or less developed.

Section *Stenotrema* Rafinesque.

*Polygyra fraterna* (Say). Moll. Chi. Area, Pl. XXX, Fig. 3.
Stations V, VIII, XII. *Fraterna* exhibits two quite distinct forms: one is small and quite umbilicated; the other is larger and either imperforate or only slightly umbilicated. The umbilicated form is larger than *Polygyra monodon* (Rackett). The two forms live in the same area and intergrade more or less completely.

## Bibliography.*


Adams, Charles C.

1900. Variation in Io. Proc. Amer. Assoc. Ad. Sci., XLIX, pp. 208–225.

1906. An Ecological Survey of Northern Michigan. Rep. State Board Geol. Surv. Mich., 1905.

Atwood, Wallace W., and Goldthwait, James W.

1908. Physical Geography of the Evanston-Waukegan Region. Bull. Ill. Geol. Surv., VII.

Baker, F. C.

1898–1902. The Mollusca of the Chicago Area. The Pelecypoda, 1898; the Gastropoda, 1902. Parts I and II. Bull. No. III, Nat. Hist. Surv. Chicago Acad. Sci.

1901. The Molluscan Fauna of the Genesee River. Amer. Nat. XXXV, pp. 659–664.

1906. Notes on a Collection of Mollusks from the Vicinity of Alpena, Michigan. Trans. Acad. Sci. St. Louis, XVI, No. 2.

Cowles, H. C.

1901. The Plant Societies of Chicago and Vicinity. Bull. Geographic Society of Chicago, No. 2.

Dall, William H.

1896. Insular Land-shell Faunas, especially as Illustrated by the Data obtained by Dr. G. Baur in the Galapagos Islands. Proc. Acad. Nat. Sci. Phil., 1896, pp. 395–459.

Call, R. Ellsworth.

1884. On the Quaternary and Recent Mollusca of the Great Basin, with Descriptions of New Forms. Bull. U. S. Geol. Surv., No. 11 (Vol. II, pp. 357–420).


*The bibliography consists of the works cited in the foregoing pages, and of a few papers on the Mollusca in which more or less emphasis is laid on ecology. The list is not exhaustive.

Elrod, Morton J.

1901. Limnological Investigations at Flathead Lake, Montana, and Vicinity, July 1899. Trans. Amer. Micr. Soc., XXII, pp. 63–80.

1902. A Biological Reconnoissance in the Vicinity of Flathead Lake. Bull. Univ. Montana, Biol. Ser. No. 3.

1903. Lectures on Flathead Lake. T. c., No. 5.

Haldeman, S. S.

1840–45. A Monograph of the Fresh-water Univalve Mollusca of the United States, Philadelphia.

Hankinson, Thomas L.

1908. A Biological Survey of Walnut Lake, Michigan. Report State Board Geol. Surv. Mich., 1907, pp. 153–288.

Headlee, T. J., and Simonton, James.

1903. Ecological Notes on the Mussels of Winona Lake. Proc. Indiana Academy Sci., 1903, pp. 173–179.

Jennings, Otto E.

1909. A Botanical Survey of Presque Isle, Erie County, Pennsylvania. Annals Carnegie Mus., V, pp. 289–421.

Needham, James G., and Betten, Cornelius.

1901. Aquatic Insects in the Adirondacks. Bull. N. Y. State Museum, XLVII.

Nylander, Olof O.

1901. Distribution of Limnæa Emarginata, Say, and the var. Mighelsi Binney, in Fish River, Aroostook Co., Maine. Printed by the author.

Pilsbry, Henry A.

1900. Mollusca of the Great Smoky Mountains. Proc. Phil. Acad. Sci., 1900, pp. 110–150.

1905. Mollusca of the Southwestern States. I: Urocoptidæ; Helicidæ of Arizona and New Mexico. Proc. Acad. Nat. Sci. Phil., 1905, pp. 211–290.

1908. Notes on Succinea ovalis Say and S. obliqua Say. Proc. Phil. Acad. Sci., 1908, pp. 45–51.

Ruthven, A. G.

1904. Notes on the Mollusks, Reptiles and Amphibians of Ontonagon County, Mich. Rep. Mich. Acad. Sci., VI, pp. 188–192.

Stearns, R. E. C.

1901. The Fossil Fresh-water Shells of the Colorado Desert, their Distribution, Environment and Variation. Proc. U. S. Nat. Mus., XXIV, pp. 271–299.

Walker, Bryant.

1892. The Shell-bearing Mollusca of Michigan. Nautilus, VI, pp. 31–35.

1906. An Illustrated Catalogue of the Mollusca of Michigan. Part I. Terrestrial Pulmonata. Rep. State Board Geol. Surv. Mich., 1905, pp. 227–531.

Walter, H. E.

1906. The Behavior of the Pond Snail, Lymnæus Elodes Say. Cold Spring Harbor Monographs, VI.

PLATE VI.

Skokie stream showing characteristic vegetation, consisting of *Salix longifolia*, *Typha latifolia* and *Sagittaria latifolia*. Station I. Photograph taken September 10, 1909. (Baker.)

PLATE VII.

General view of Skokie Marsh, showing the "islands." Looking southeast. Station II. Photograph taken September 10, 1909. (Baker.)

PLATE VIII.

Fig. 1. Nearer view of the "islands" showing conspicuous vegetation, *Typha latifolia* and *Calamagrostis canadensis* surrounding the "islands." Photograph taken September 5, 1908. (Woodruff.)

Fig. 2. In Skokie Marsh, showing height of bluejoint grass, *Calamagrostis canadensis*. Photograph taken September 5, 1908. (Woodruff.)

PLATE IX.

Wooded area on west edge of Skokie Marsh, showing pond-like area in center occupied by *Typha latifolia*. Stations III–V. Photograph taken September 5, 1908. (Woodruff.)

PLATE X.

Large marshy pond west of Northwestern Railroad cut-off and south of the Glencoe Road. Station VII. The characteristic vegetation is *Iris versicolor* and *Typha latifolia*. The forest is seen in the background. View looking south. Photograph taken September 10, 1909. (Baker.)

PLATE XI.

A nearer view of the pond shown in Plate X. The heavy central growth of *Typha* is conspicuous. Photograph taken September 10, 1909. (Baker.)

# Plate XII.

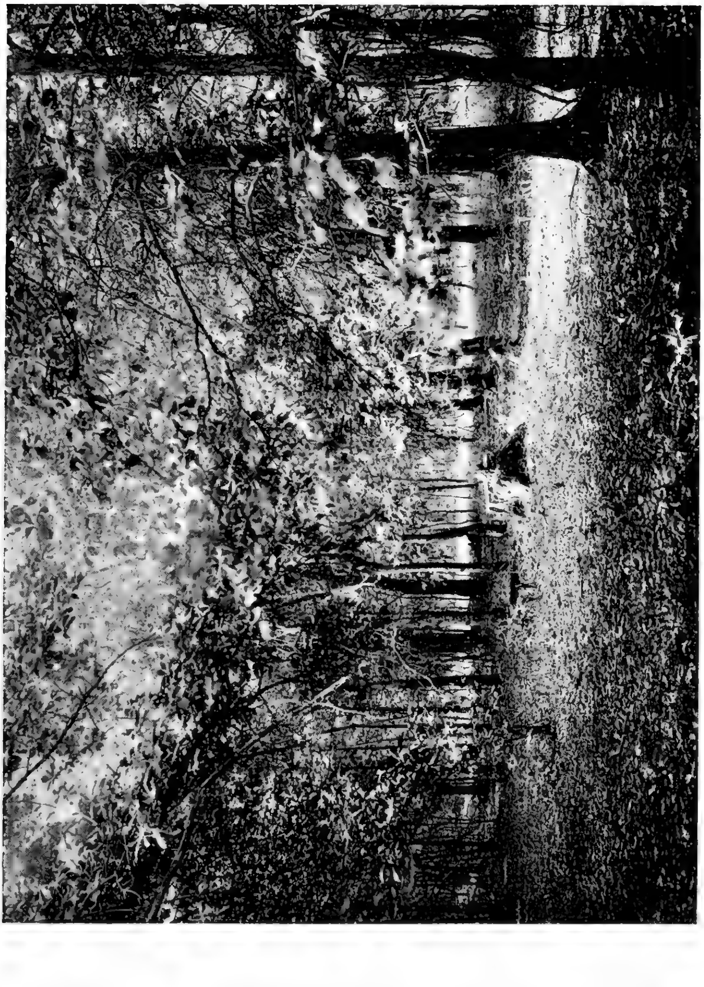
Fig. 1. The same pond (Pl. X.) from the east, looking west. The heavy growth of *Iris* is noteworthy. Photograph taken September 5, 1908. (Woodruff.)

Fig. 2. Nearer view of the pond shown in Plate XIII., showing heavy growth of *Typha latifolia* which had been cut by the farmer when that picture was taken. Photograph taken September 5, 1908. (Woodruff.)

PLATE XIII.

Small pond west of Northwestern Railroad cut-off, north of open field. Station XIV. The vegetation is principally *Typha*, *Iris* and *Cephalanthus*. View looking north. Photograph taken September 10, 1909. (Baker.)

PLATE XIV.

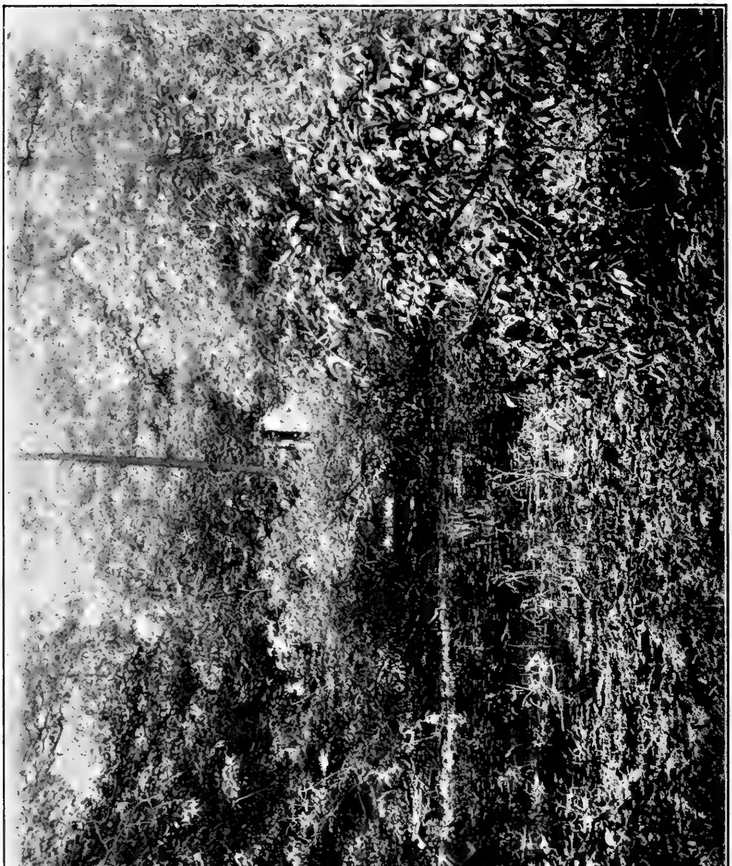


Open area in forest near Station XIV. The ground is covered with leaves, under which such molluscan species as *Lymnæa caperata*, *Aplexa hypnorum* and *Sphærium occidentale* may be found. Photograph taken September 5, 1908. (Woodruff.)

PLATE XV.

Small pond east of the East Branch of the Chicago River. Station XVI. The conspicuous vegetation is *Typha* and *Cephalanthus*. Photograph taken September 5, 1908. (Woodruff.)

PLATE XVI.



Small pond in woods bordering east bank of East Branch of the Chicago River. Station XVIII. The prominent vegetation is *Cephalanthus occidentalis*. Photograph taken September 10, 1909. (Baker.)

PLATE XVII.

Fig. 1. Station XVIII. Photograph taken September 5, 1908. A comparison of this figure with the previous plate will illustrate the difference in rainfall in 1908 and 1909. When the photograph was taken the bottom of the pond was dry and sun-baked. (Woodruff.)

Fig. 2. East Branch of the Chicago River, looking south from Glencoe road. Photograph taken May 18, 1908. Note the width of the river. (Woodruff.)

# Plate XVIII.

Fig. 1. East Branch of the Chicago River, looking north from flood-plain. Photograph taken September 5, 1908. Compare the river bed with Plate XVII, 2. These two plates well illustrate spring and fall conditions in this area. (Woodruff.)

Fig. 2. North Branch of the Chicago River, looking north from Shermerville. Photograph taken at high-water stage. May 18, 1908. (Woodruff.)

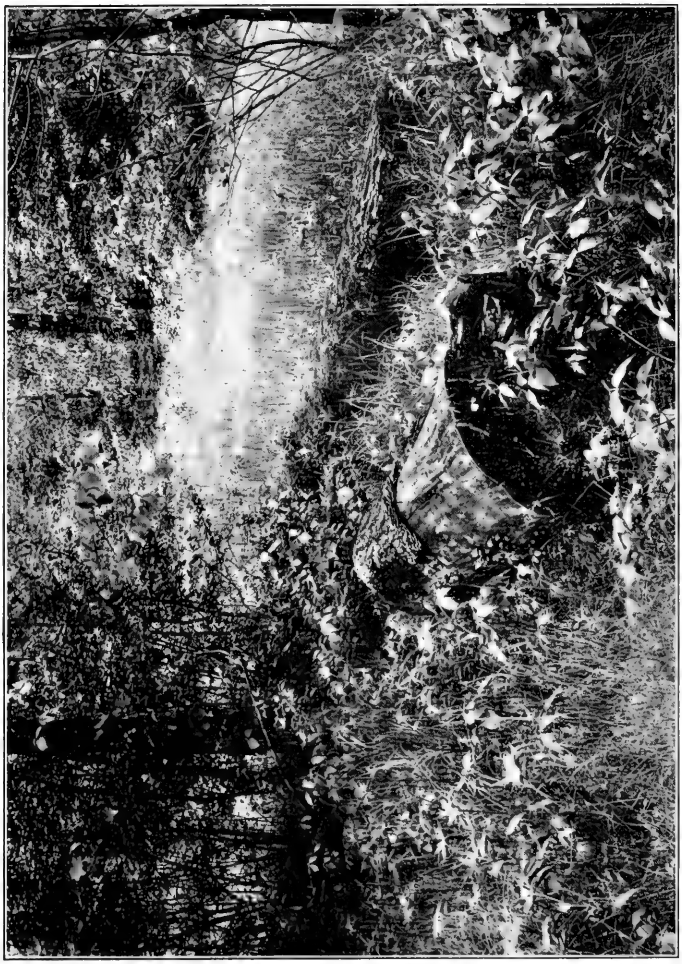
PLATE XIX.

Flood-plain, East Branch of the Chicago River, looking north. The characteristic vegetation is *Iris versicolor*. Photograph taken May 18, 1908. (Woodruff.)

PLATE XX.

Area north of Glencoe road and west of the East Branch of the Chicago River. An open forest with an abundance of ground vegetation. *Rudbeckia laciniata* and *Trillium* are the notable ground plants. Photograph taken May 18, 1908. (Woodruff.)

PLATE XXI.



Old log habitat. Station XVIII., area same as that shown in Plate XX. Photograph taken May 18, 1908. (Woodruff.)

PLATE XXII.

Pond in woods, one mile west of East Branch of the Chicago River. Note the absence of aquatic vegetation, such as *Iris*, *Typha*, *Cephalanthus*, etc. The forest trees, *Carya*, *Quercus* and *Ulmus* are conspicuous. View looking north. Photograph taken September 5, 1908. (Woodruff.)

PLATE XXIII.

The same pond as that shown in Plate XXII. Fall condition in 1909, after a season of good rainfall. Photograph taken September 10, 1909. (Baker.)

## Plate XXIV.

Fig. 1. The same pond as that shown in Plate XXII. Usual fall condition, after a season of dry weather. Photograph taken September 5, 1908. (Woodruff.)

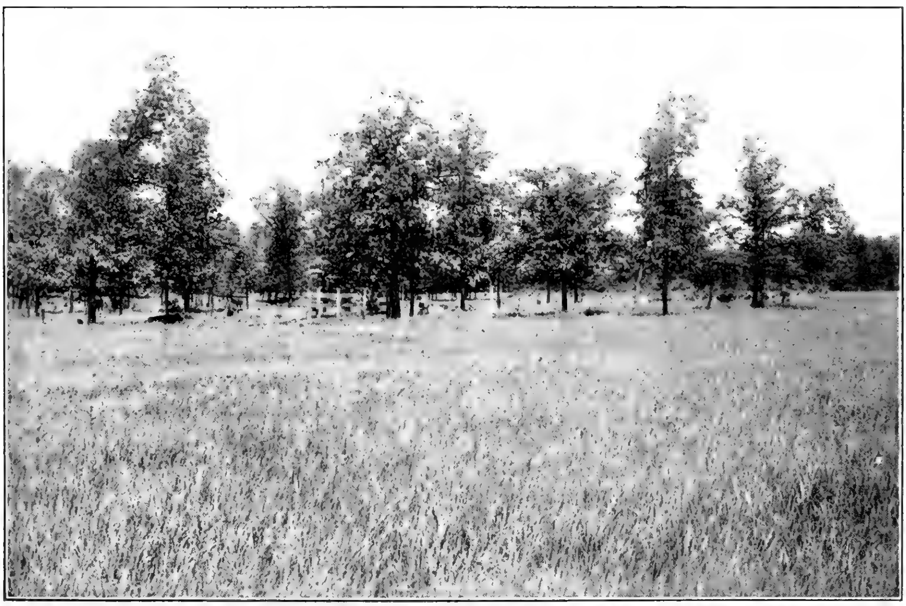
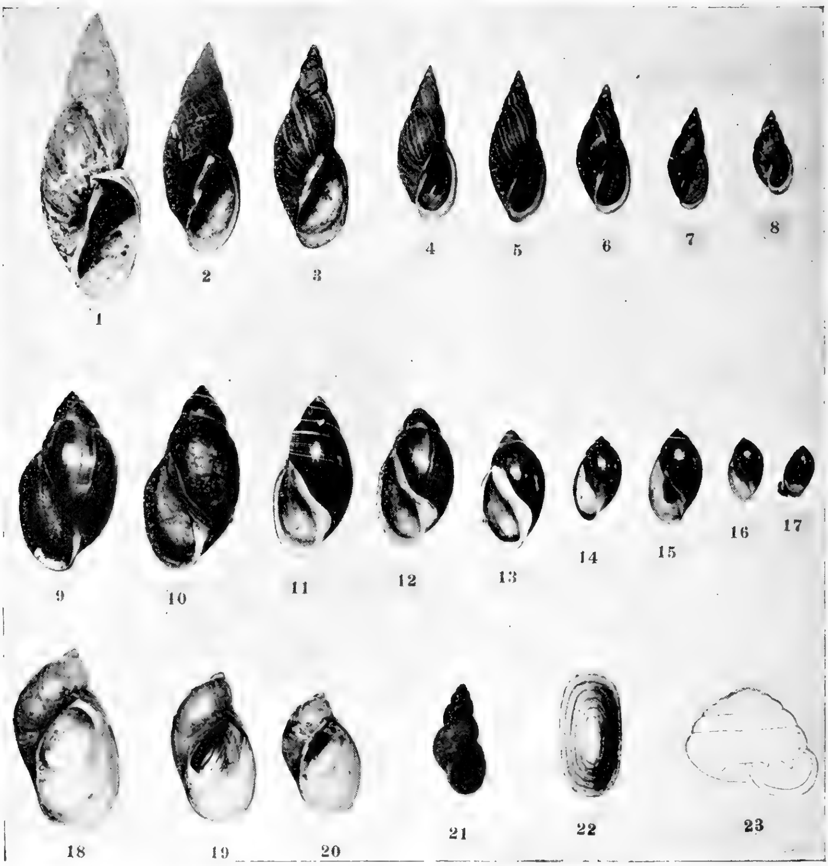


Fig. 2. Open fields north of Glencoe road, near Shermerville. These fields are used as pastures for cattle. Photograph taken May 18, 1908. (Woodruff.)

## Plate XXV.




Some Skokie mollusks

1. *Lymnæa reflexa* Say. Adult.
2, 3. *Lymnæa reflexa crystalensis* Baker. Immature *reflexa*.
4–8. *Lymnæa palustris michiganensis* Walker. Juvenile *reflexa*.
9–13. *Physa gyrina* Say. Adult.
14–17. *Physa oleacea* Tryon. Immature *gyrina*.
18, 19. *Succinea ovalis optima* Pilsbry. Possibly senile form of *ovalis*.
20. *Succinea ovalis* Say.
21. *Lymnæa parva sterkii* Baker.
22. *Ancylus parallelus* Hald. (After Fig. 6, Pl. I., Hald. Monogr.)
23. *Strobilops virgo* (Pilsbry). (After Fig. 120, Walker's Moll. Mich.)

Figures 1—20 enlarged 1½ diameters; fig. 21 enlarged 3 diameters; fig. 22 greatly enlarged; fig. 23 enlarged about 10 diameters.

# BULLETIN

OF THE

# ILLINOIS STATE LABORATORY

OF

# NATURAL HISTORY

URBANA, ILLINOIS, U. S. A.

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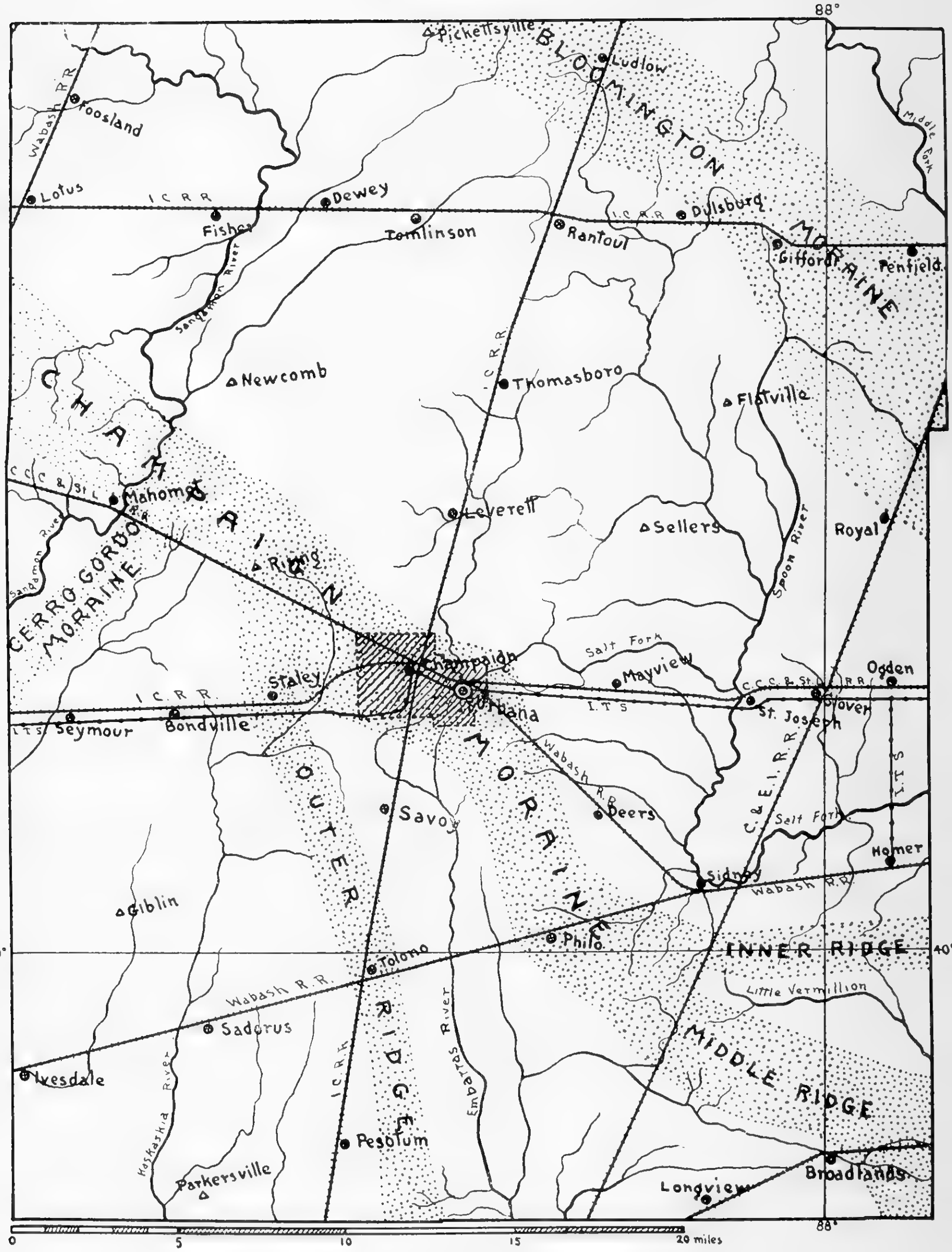
## A STUDY OF THE MAMMALS OF CHAMPAIGN COUNTY, ILLINOIS.


BY

FRANK ELMER WOOD, A. B.




MAP OF CHAMPAIGN COUNTY, ILLINOIS.

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Article V.—*A Study of the Mammals of Champaign County, Illinois.* By Frank Elmer Wood.

## Topography and Mammalian Habitats and Associations.

Champaign county lies in the east-central part of the State of Illinois. It is rectangular in shape, extending thirty-six miles north and south and about twenty-eight miles east and west, its area being almost exactly 1000 square miles. Urbana, the county seat and the seat of the University of Illinois, is near the center of the county. The geographical location of the university observatory is 40° 6′ 20″ north latitude and 88° 13′ 28″ west longitude.

The general topography of the county is that characteristic of the prairie region of the Mississippi Valley. It is essentially a level or gently rolling plain very moderately diversified by moraine ridges and shallow river valleys. The highest elevation recorded for the county is 830 feet above sea-level and the lowest is 610—giving an extreme variation of 220 feet in the thousand square miles of territory.

The county lies entirely within the limits of the glacial deposits of the Wisconsin epoch. Two morainic systems of the Wisconsin drift cross the county. The outer crest of the Bloomington moraine crosses the northeast corner. The ridge is two to five miles broad, and rises to an average of about 50 feet above the plain to the southwest. While the ridge is well defined in places, for a large part within the county it is represented only by low knolls and winding ridges. Between these are broad shallow basins and sags that are often difficult to drain. The Champaign moraine crosses the county from northwest to southeast a little south of the center. At its entrance into the county on the western border the system consists of a single ridge, but near Champaign divides into three distinct ridges which continue, separately, in easterly, southeasterly, and southerly directions across the county.

The depth of the glacial deposit southwest of the Champaign moraine is 100 feet or less. North of this it is considerably more, and Leverett estimates the average depth for the county as about

200 feet. There are no natural outcrops of the underlying rock within the county limits.

A glance at a map representing the rivers of the state will show that a number of important rivers rise either within the county or immediately north of it and flow in all directions but a northerly one. The Sangamon crosses the northwest corner of the county, and with several prairie streams or tributaries drains that quarter of the county. The Middle Fork of the Big Vermilion (of the Wabash) just enters the northeast corner, and the various branches of the Salt Fork of the same river drain the most of the eastern half of the county. The southwest quarter is drained by the head waters of the Kaskaskia and Embarras rivers. These last two streams are in this section little more than prairie creeks with steep earth banks and undeveloped treeless valleys. The Sangamon and the larger tributaries of the Big Vermilion have the same general characteristics. In the vicinity of the moraines they lie in narrow, well-defined valleys, which usually rise in steep bluffs on one side, 30 to 70 feet or more in height. The flood-plain, usually narrow, may reach a quarter of a mile in width. Beyond the moraines, in the till, the valleys are lower and not so well defined. All these streams are subject to heavy floods. In summer, however, their muddy waters flow between steep earth banks 4 to 8 feet below the flood-plain.

Originally a belt of timber, sometimes narrow, but sometimes attaining a width of nearly two miles, extended along these larger streams. It was almost invariably broader on the east and north sides of a stream than on the west and south sides, a possible explanation being that woods on the south and west would be more exposed to prairie fires driven by the prevailing southwest winds. It is needless to say that this primitive condition has been greatly modified since the settlement of the country. The steep bluffs along the rivers are in general still covered with timber, though it is usually of small size and recent growth, and dense thickets and woods with heavy undergrowth still occur along the river valleys and on the flood-plains; but, for the most part, the broad belt of forest that formerly encroached on the prairies along the streams is represented only by scattered groves of second growth, and these are usually much thinned out, and the underbrush is kept down by grazing. These river-belt areas still furnish the chief cover and highway for the migration of many of the larger mammals left within our area.

In these areas there is still considerable pasture or fallow land. There is even an occasional remnant of a rail fence, while thickets in the fence corners, brush along the fences, and other forms of agricultural untidiness are a protection to wild animal life in general.

Outside these river valleys there were a few scattered groves, from 20 to 160 acres in extent, which served as landmarks and were known by special names for many miles around. With the exception of the moraines and the narrow belts along the larger streams the country was naturally a very gently rolling prairie. It bore, too, the character of a country of recent geological age where drainage was still undeveloped. The windrows of glacial drift were very imperfectly cut through, and shut in the surface water in shallow basins. The encroaching vegetation and vegetable deposits had changed these basins to what were shallow sloughs or marshy lakes in a rainy season, but became soggy meadows in time of drought. Though the main streams had cut deep into the till, the smaller headwaters had eroded but little. Indeed, along their upper courses their erosive action must have been zero, and they represented little more than the course along which the drainage waters seeped their way, through dense vegetation and matted debris, to a lower level.

For detailed study of the distribution of its mammals, the county may be divided into

| | |
|---|---|
| Till plains, | Groves, |
| Moraine ridges, | Permanent pastures, |
| Wooded bluffs and ravines, | Flood-plains. |

## TILL PLAINS.

(Plate XXVI., Fig. 1.)

Under this designation are included the extensive, nearly level prairie areas lying between the higher, more uneven moraine belts. These plains are the most characteristic and the most extensive feature of the topography of the county. They vary little in level, often less than five feet within a square mile. Portions were originally wet and swampy, but all are now drained and under thorough cultivation. Some of these areas, however, although extensively underdrained and capable of thorough cultivation in ordinary years, are nevertheless sometimes covered by a few inches of water during the early spring, and such areas—usually of small extent—

are as destitute of permanent mammalian life as though they were perpetual swamps.

The land is exceedingly fertile, and every square rod that can not be kept under constant cultivation is a chronic annoyance to its owner. The fields are large—except in the vicinity of towns—running from 40 to 160 acres, or even more. Cultivation is thorough, and but few waste places along fences, ditches, etc., are permitted. There are but few hedges, orchards and groves are small and uncommon, and but little land is left in permanent pasturage. Narrow strips, barely two feet wide, along the wire fences, and belts a dozen feet in width each side of the roads—which are regularly laid out a mile apart—with limited spaces around the dwellings, are about all the land not turned up by the plough three years out of four.

Apparently nothing but a veritable desert could be more unfavorable for mammalian life than these large well-tilled fields. They contain, however, considerable numbers of mammals at all times, and, really, an abundance of them at certain seasons. A common permanent resident of such fields—always present unless driven out by standing water—is the white-footed prairie-mouse, *Peromyscus maniculatus bairdii.* An illustration, based on repeated experiments, may throw some light on the abundance of this species. In large corn fields of 80 to 160 acres, when the corn was about one foot in height and was being repeatedly harrowed and kept almost absolutely free from weeds, I repeatedly set traps near the center of the field, at every tenth hill along the rows, with no regard to any indication of the presence of mice. The average result from one night's setting was a white-footed mouse in about one trap in ten. Very rarely a specimen of the short-tailed shrew (*Blarina brevicauda*) was taken. If these traps were set near the edge of the field, the proportion of traps containing animals was increased; and if near an old hedge, waste land, or roadside, specimens of the prairie-vole (*Microtus austerus*) might be taken, and the average of successful traps would rise to one in five for a single night. The same average would hold for traps set at the same distance apart in stubble or corn fields from which the crop had been cut and removed. My averages of successful traps set in the same way across a corn field, where the corn had been husked without cutting, was also about one in five.

When one considers how small a proportion of the animals present would be likely to find traps thus set across a field, one is forced to conclude that the number actually present at all times may be considerable, even in the middle of the best-cultivated fields. If traps are set along fences between such fields, at every post, the number containing animals will rise to one third or even one half of the traps. The average number of birds found in the corn fields of this belt was nearly one to the acre, and the number of mammals present, even in the middle of the larger fields, can hardly be less, while for the whole belt it must be considerably greater. During spring and early summer, as we have said, white-footed mice constitute the great bulk of the mammalian life in the center of these large fields. Near the edge the mole, *Scalopus aquaticus*, may be present, sometimes in considerable numbers, but it seldoms penetrates more than 50 yards into the field. Shrews, voles, and gophers are present along the fences and in adjoining fields not too recently disturbed, and make short incursions into the corn fields at that time of year. But in fall, if the grain or corn be shocked and allowed to stand a fortnight or so, traps set by the shocks show quite different conditions. The following may serve as a rather extreme illustration. In a corn field on the university farm where the white-footed mouse had been taken early in the year (1907), after the corn had been cut and shocked for some time fifty traps were set over night, one by each of as many consecutive shocks. The next morning thirty-seven of these traps contained specimens—one of them a single house-mouse, *Mus musculus*. In 1908, thirty-one traps were set in the same field under similar conditions except that the corn had not been shocked so long, and only ten specimens were taken, nine of which were house-mice and one was a white-foot. At first the conclusion was drawn that the house-mice had entirely driven out the prairie-mice. However, when traps were set in an adjoining part of the same field from which the shocks had been removed, the usual number of white-footed mice was taken, with the addition of one specimen of the house-mouse. Evidently the house-mice invaded the field after the corn was cut, and the prairie-mice were either driven from the shelter of the shocks or disdained it. Probably the former is the truth, for I have often taken them by recently cut shocks of corn and grain.

Wherever there is a bit of waste ground where grass and weeds can grow undisturbed the prairie-vole and, more rarely, the Pennsylvania meadow-mouse (*Microtus pennsylvanicus*) are present, and together with the short-tailed shrew will invade the fields soon after cultivation ceases. These and the house-mouse are always taken in fall, unless the ground is quite cleared of standing or shocked corn or grain. In clover fields, meadow-lands, pastures, and alfalfa fields, especially when these crops have grown on the same land for several successive years, the prairie-vole becomes the dominant form, with the mole a close second, especially around the margin.

Wherever there are piles of rubbish, old ricks, compost heaps, etc., these serve as homes of house-mice, and, if large, of rats, *Mus norvegicus*. From these centers the former spread out into the adjoining territory. Along the small streams—mere drainage ditches usually—so long as they contain a trace of water, muskrats are really abundant. These ditches serve, too, as highways for minks and weasels. The former especially take refuge in the open mouths of the tile drains. When the ditches are a little larger and their banks are bordered by a rank growth of grass and weeds, this furnishes shelter for rabbits the whole year through. Rabbits are abundant, too, during fall and early winter, finding a precarious shelter under clods and fallen stalks during the light winter snows of this part of the state.

Where the till plains are devoted to pasture, or where they border the moraines, the striped gopher, *Citellus tridecemlineatus*, and the gray gopher, *C. franklinii*, are present, and enter corn and grain fields during summer and fall. The latter, so far as my own observations go, seems to spread out farther into fields of alfalfa and clover, while the striped gopher often takes up its residence in corn fields immediately after planting—to the exasperation of the farmer. Under usual conditions, the white-footed wood-mouse, *Peromyscus leucopus*, is not found in this type of locality. If, however, there be present anywhere a small grove, a neglected thicket, or an old hedge, one is almost sure to find this mouse. It is surprising how little of such shelter suffices for it, and yet it is almost never found without any shelter at all.

Skunks are occasionally seen in the fields in these plains, but they are not common.

## MORAINE RIDGES.

(Map.)

To one accustomed to a hilly or mountainous country only, these elevations would seem too insignificant for consideration either as features of the topography or as factors in the distribution of animal life. They seldom stand more than eighty feet above the plains, and their rise is usually distributed over a mile in extent. But to those long accustomed to a prairie region they are striking objects, and even have something of quiet grandeur. Except in the vicinity of rivers, these moraines were destitute of trees, and were classed, with the till plains, as prairie by early settlers. The species of plants and animals found on these ridges are largely the same as those found on the plains, and the difference between the fauna and flora of the two is due chiefly to the relative abundance of the species in the two regions. The peculiarities of the moraines are due to better drainage, to the results of erosion, and to the greater exposure to the wind. In consequence of the better drainage aquatic forms are absent except in sags or in depressions. Because of erosion and leaching the black soil on the ridges is less deep and perhaps less fertile than that of the plains, and, consequently, under original conditions the vegetation was less luxuriant on the moraines. The exposure to wind, which perhaps so far as mammals are concerned is a negligible factor during the summer, becomes a very important one during the winter.

The conditions of cultivation on the ridges are practically the same as those on the plains.

These ridges are the favorite habitat of the striped gopher. Wherever the surface of the ground has been undisturbed long enough for these gophers to dare to dig their burrows one will be sure to hear their plaintive, questioning whistle on any bright summer day. Moles also are more abundant on the slopes of the moraines than anywhere else in the county. Under certain conditions the white-footed prairie-mouse is also abundant. These three species are often found together, and certain spots containing a few acres inhabited by them have the densest mammalian life that I have seen in the county. Their burrows are so close together and all three animals are so abundant, that I believe they do not interfere with each other in any way.

The gray gopher also is not uncommon along the edge of the moraines, but is apparently more apt to wander into the lower land than the striped gopher is. House-mice and rats are as abundant here as anywhere if the proper shelter is present. The prairie-vole is sometimes abundant, especially in meadows that have been for some years in grass or clover.

The sags in the moraines are usually occupied by a drainage ditch or natural watercourse, with a narrow border of waste land covered with rank vegetation. These belts are hiding-places for rabbits and hunting-grounds for weasels. Muskrats and minks follow the watercourses to their very sources.

### WOODED BLUFFS.

As we have said, the principal streams were originally bordered on each side by a strip of timber of varying width. Under wooded bluffs we include such portions of this timber as are in the immediate vicinity of the streams or are practically continuous with woodland that is so situated. Where the original belt of timber was broad, certain portions have been isolated in the process of deforestation, and these isolated areas are much modified as regards both fauna and flora, and have been classed as groves.

In the early days the woods formed an almost unbroken highway for large animals from the extensive forests of the south and east. Along them, bears, wildcats, timber-wolves, and possibly pumas, entered the county. Later the last deer found refuge there. Although these wooded belts have been greatly narrowed and much thinned, they are still practically continuous for many miles, and so furnish a large range of woodland, and are the chief retreat of nearly all the larger mammals still found in the county. Wolves have been found along the Sangamon River up to a recent date, and probably a few still exist there. Whatever foxes, red or gray, may yet be in the county must den in these woods. They are the chief habitat of coons and opossums, although the latter have of late years taken to wandering long distances into the prairie. Skunks also are abundant in such localities, hunting extensively over the adjoining fields, but retreating to the bluff regions to dig their burrows. Kennicott stated in 1856, that the gray squirrel was restricted to the dense woods along the rivers. If there are any within the county limits, still in a state of nature, they are to be looked for in such localities. Fox-squirrels are in general most abundant in these sections—probably because of better protection rather than from choice. Where they have the protection of groves they soon become quite numerous. The chipmunk is also practically limited to this region and its immediate vicinity. Bats are most abundant here, and the only records I have of flying squirrels within the county were also from this situation.

In summer the white-footed wood-mouse may be found in the margins of the woods or under shelter in the fields immediately adjoining, although nearly a hundred traps set in the middle of dense woods at that season failed to catch a single specimen. Late in fall and in winter, however, they were abundant in such localities. In fact, the middle of the larger, denser woods is surprisingly destitute of all animal life during the summer. Late in autumn the animals have returned, or at least appear again. The larger mammals are probably no more rare then than ever, but the smaller species seem to be lacking. At any rate, my trapping, persisted in for some time, was a complete failure then, though yielding an abundance of specimens in early winter. This fact supports the belief of most careful observers that wood-mice, voles, and shrews make a yearly migration to the cultivated fields in the spring, returning to the shelter of the woods in winter. I am inclined to believe that it is quite late in the year before all are back in winter quarters.

## GROVES.

By groves we mean the small patches of woodland surrounded by treeless territory and not immediately connected by woodland with the woods of the river bluffs. In a few cases they have been planted, and a few are the remains of groves that were standing isolated in the prairie when the country was settled. It is possible that a few are self-sown extensions of the original woods and have grown up since white men came; but by far the most of them are portions of the old wooded tracts along the streams, and so are connected in origin with the woods of the bluffs. But whatever the origin, so far as the mammalian fauna is concerned the conditions are similar in all. The species of trees composing them are the same as those given for the bluffs, with walnut, the hickories, and occasionally green ash also, conspicuous. In general the trees are of medium size, and the woods are open. These wood-lots are usually closely pastured, and underbrush is lacking, clusters of pokeberry and clumps of hawthorn being about the only thicket growth to be seen. To a certain degree the fauna, too, is distinguished from that of the wooded bluffs by what it lacks rather than by what it comprises. Foxes and coons, with the larger mammals, are lacking, and the opossum is generally only a visitor in these groves. The gray squirrel is not found in them except in a semi-domesticated state in towns, and the chipmunk is seen in them only in the vicinity of the wooded bluffs. On the other hand, some wood-mice, shrews, voles, and perhaps house-mice may be found at any season, and are abundant there in winter. The fox-squirrels soon take possession of groves in considerable numbers if they are not disturbed, but more often they have been exterminated in such places. The open portions of the wood-lots are usually undermined by a close mesh of mole-runs, and cultivated fields near by are sure to be infested by these animals.

Bats are not uncommon, and find roosting places in the hollow trees, and skunks and woodchucks may dig their dens under old stumps or other shelter.

These groves, in winter especially, are a favorite hiding-place for rabbits. After the first snow falls in early winter the hunters are sure to find them under nearly every brush-heap, fallen tree, or similar hiding-place.

### PERMANENT PASTURES.

(Plate XXVI., Fig. 2.)

As we have seen, but little of the original prairie is used permanently for grazing, and the permanent pastures of the county are for the most part portions of the country from which the timber has been removed. In general, stumps, old half-decayed logs, thickets, and scattered trees remain as relics of the original condition of the land. The pasturing is usually rather close, but the waste growth of weeds and coarse grasses in swampy places and around thickets furnishes shelter for birds, reptiles, and small mammals.

These pastures are the favorite resort of the white-footed wood-mouse, and it is as characteristic of them as the prairie white-foot is of the corn fields of the prairie. Every large old stump, decayed log, brush-heap, or similar shelter is pretty sure to be the home of one. Next in real abundance, though even more conspicuous, are the striped gopher and the mole. Both of these, however, prefer the richer fallow lands of the prairie, and in spite of persecution are more abundant there. Voles are sometimes abundant where the dense shelter of grass they require is present, and shrews are often taken.

In the northern part of the county, where woodchucks are found, their burrows are most common in the pasture-lands. Probably this would not be the case, however, if the farmers on the moraines were accustomed to keep their fields in clover for several successive seasons.

The other mammals found in the pasture-lands are transient visitors rather than permanent residents. The pastures are favorite hunting-grounds of the skunk, and it occasionally digs its burrow in the edge of a lot. In the vicinity of woodland, rail fences, or other continuous shelter, chipmunks may occasionally venture into the fields, and rabbits visit them and, rarely, make their nests in a thicket there.

The fact that these permanent pastures are in general much poorer in smaller mammalian life than the moraines of the prairie is not evident at first, but careful examination will make it apparent. The reason is plain. On the moraine belts there is abundant food and a comparative scarcity of larger *Carnivora* and birds of prey. The permanent pastures furnish less food, and are for the most part in the vicinity of woodlands that are the habitat of skunks, weasels, coons, and foxes, and afford nesting places for hawks and owls. It is another illustration of how little the direct persecution of man affects these smaller animals compared with the injury inflicted on them by their natural enemies.

### FLOOD-PLAINS.

The portions of the river valleys subject to overflow for a longer or shorter period each year, though forming but a small part of the county, furnish a habitat of peculiar interest. For the most part these flooded tracts are from four to six feet above the summer level of the water, though unusual floods may rise much higher than that. For example, the high-water mark reached by the Sangamon in the spring of 1908, was fourteen feet above the water-level in September. These bottoms are usually sparingly wooded. The streams are often fringed with willows, the lower bottoms are treeless or bear a scattered growth of sycamore, elm, ash, and button-bush, while along the edge of the flood-plain, oak, water-maple, honey-locust, and hawthorn may be found. Unless the timber is heavy and connected with a tract of wooded bluff it seems to make little or no difference in the mammals found. Among those found at present in the county, only the muskrat and the mink can be truly at home in these flood-plains at all times; but a number of small animals are abundant in these localities during the summer. White-footed wood-mice and short-tailed shrews (*Blarina brevicauda*) are found wherever the ground is dry and shelter, in the form of driftwood, stumps, etc., is present. Prairie-voles are common down to the zone of the sedges, but seldom in that zone or below it. Weasels hunt over the bottoms, and rabbits hide there. The more heavily timbered portions are a favorite resort of coons.

As the river-bottoms were in general the last portions of the country from which, at a certain stage in the development of this part of the country, the original heavy timber was removed, they furnished a last retreat for deer and other large game.

What becomes of the smaller mammals when these plains are under water? During the spring floods I have found voles clinging to the stumps that rose above the water. When approached they plunged into the water and swam off, or escaped by diving. I am told that in high water on the Illinois River, many white-footed wood-mice are seen on the trees above the water. Probably the mice and shrews both escape in a similar way in this locality during floods. The runways of moles are common along the edge of the flood-plain, but almost never occur at any great distance below high-water mark. In fact, their presence serves as a reliable guide to the limit of ordinary high water.

In spite of the fact that these small mammals swim so easily, the time of flood must be one of great mortality among them. The flood-plains are often forty rods or more across, and these animals are not strong enough swimmers to breast a moderate current, nor is it likely that they can live in the water a long time. Moreover, the time of high water is quite often the breeding season of these animals, and the very young must all perish. In the case of the comparatively small bottom-lands in this county it might be supposed that the mammalian population was kept up by immigration each summer from the surrounding higher ground, but that can hardly be true for the extensive tracts submerged each year along the Illinois and other large rivers.

# DISCUSSION OF SPECIES.

## POUCHED ANIMALS.

## *MARSUPIALIA.*

### OPOSSUM.

*Didelphys virginiana* Kerr.

(Animal Kingdom, 1792, p. 193.)

Under natural conditions the opossum was an animal of the woods and not of the prairie section, being especially abundant in the belts of heavy timber along the rivers; but as with advancing civilization these woods have been thinned out, and, on the other hand, as more shelter is furnished by groves, orchards, hedges, etc., it is possible that, though fewer in number, opossums have become more generally spread over the country than under original conditions. Although it can hardly be said of them in our vicinity that they are "equally at home in the lumber piles and hen-roosts of the town or among the untrodden haunts of the wilderness," they are nevertheless occasional visitors to farmyards and hen-roosts in the vicinity of our towns.

In their diet they are well nigh omnivorous, showing a decided preference, however, for eggs, young birds, and certain wild fruits, as persimmons and papaws. They also eat nuts, insects, and small animals, and, when pressed by hunger, they may feed on carrion.

The range of the opossum is throughout the eastern half of the United States north to the Great Lakes. It has been taken in New York at Schoharie, in Cayuga county, and near Rochester; near Erie in Pennsylvania, Ann Arbor in Michigan, and in the southern tier of counties in Wisconsin. It is common in eastern Kansas, and has been taken in Texas at Mason, San Antonio, and near Matagorda Bay. It is also found on Long Island, and has been introduced in Massachusetts and Rhode Island. Its range to the northeast has apparently increased during recent times, it having entered New York from the south and spread to the limits mentioned above.

The species shows a tendency to become smaller and darker toward the south, becoming the subspecies *pigra* of Bangs, which is found in Georgia, Florida, and the Gulf states.

Gestation in the opossum lasts about seventeen days. From six to as many as sixteen, or more, may be produced in a litter, and available evidence goes to show that there may be three litters during the year—all between January and the last of June. The female is often found accompanied by the young of more than one litter. At parturition the female lies on one side, curling up so as to bring the vulva near the opening of the marsupial sac. The young as brought forth are pushed into the sac and attach themselves to the teats, remaining continuously attached for four weeks, and for much of the time during the three weeks following. They are only a quarter of an inch long and weigh but four grains at birth. They are hairless, and their eyes and ears are closed. The mouth is a minute opening just able to receive the slender teats of the mother. Growth is very rapid. The young leave the pouch when about two months old, weighing then 400 to 450 grains. Even at the first, however, they exercise all the functions of other young animals, breathing, eating, digesting, defecating, etc., and are by no means the unformed egg or embryonic mass they were once supposed to be. The tail is prehensile, and the very young are able to support themselves by one twentieth of its length.

In general the adults live separately, but pair a short time during the rutting season. At this time the males are exceedingly pugnacious and jealous of each other. They hide in hollow trees, logs, etc., but are said to be of a wandering habit, not remaining long in one locality.

Owing to peculiarities of anatomical structure, the movements of the opossum, if not graceful, are at least unusually free and varied. The thumb and hallux are both opposable, and Coues asserts that the opossum is functionally as truly four-handed as are most of the monkeys. The movements of the feet as a whole are nearly as free as those of the human hand. The body is easily curled into a ball, and lateral movements are unusually free. The tail itself serves as a fifth hand, and possesses so much flexibility and strength that the animal can easily support itself by a small portion of the tip. It is capable not only of flexion in a single plane, but also of a twisting motion by which it can be wrapped in a spiral around a slender support, even when that support is nearly parallel with the axis of the tail itself. When not in use it is carried bent under at the tip in the shape of an interrogation-point. The agility and serpent-like flexibility of the opossum is illustrated by the process of regaining a support to which it is attached by its tail. It is thus described by Coues: "It bends the neck and shoulders strongly forward, reaches upward with its fore paws until it can catch hold of the loosely hanging hind feet; further action of all four extremities carries the paws to the root of the tail, which is firmly grasped, when the animal climbs up its tail 'hand over hand' until the point of support is laid hold of, after which by a peculiar squirming motion of the whole body the desired altitude is attained."

The opossum's habit of feigning death when attacked is well known, and "playing possum" has become a proverbial expression. Though this peculiarity has been often studied, there seems to be as yet no uniformity of belief among scientists as to how far the act is a conscious and deliberate one and how far an involuntary cataleptic or hypnotic trance due to fear. Certain it is that however advantageous the peculiarity may sometimes be, at other times it is as surely a disadvantage.

In captivity the opossum is an uninteresting pet, sleeping during the day and feeding mostly at night. When disturbed it shows its resentment by a hiss and a lazy, grin-like baring of the teeth.

## HOOFED ANIMALS.

## *UNGULATA.*

### AMERICAN ELK.

*Cervus canadensis* (Erxleben).

*Cervus elaphus canadensis* Erxl., Syst. Regn. Anim., I., 1777, p. 305.
*Elaphus canadensis* Ray, Kennicott, in Trans. Ill. State Agr. Soc., I., 1853–54, p. 580.

Kennicott says that several elks were shot in Cook county and that an elk was killed near Mt. Carmel in 1830. I have not been able to obtain any proof that one was ever seen by the settlers in this county. Elks have been long extinct throughout the state.

### VIRGINIAN WHITE-TAILED DEER.

*Odocoileus americanus* (Erxleben).

*Cervus dama americanus* Erxl., Syst. Regn. Anim., I., 1777, p. 312.
*Odocoileus speleus* Raf., Atlantic Journ., I., 1832, No. 3, p. 109.

This is the common deer of the eastern United States, and was originally found almost everywhere from New York to Florida and west to the Missouri River. It is still found throughout this range wherever not exterminated, and in any of the wilder portions, if protected, soon becomes common. The first settlers found deer very abundant in this part of the country. As the wolves were killed or driven off, the deer became more plentiful, reaching their greatest abundance between 1845 and 1855. They were common in the parts of the county bordering the larger rivers till 1865, and it seems certain that they still bred within the county limits several years after that date. One was seen near Homer as late as 1880. They are still seen occasionally in the southern part of the state near the Mississippi River. The hunters there believe that they cross the river from Missouri. I have no evidence that they still breed within this state.

### BISON; AMERICAN BUFFALO.

*Bison bison* (Linnæus).

*Bos bison* Linn., Syst. Nat., I., 1758, p. 72.

The earliest explorers of Illinois all speak of the great herds of buffalo seen. It seems impossible to fix with any degree of accuracy the date of their disappearance from this locality, but it seems probable that it was before 1815. Certainly they were gone before the first settlers came. There were several deeply worn trails crossing the county in various directions, and these were used as roads by the early settlers. Mud-holes in which they had wallowed—called buffalo-wallows by the frontiersmen—were also common, and easily recognized till the land was cultivated. In Vermilion county—adjoining Champaign county on the east—there was a salt-lick toward which several buffalo-trails converged.

## GNAWING ANIMALS.

### *RODENTIA.*

#### FOX-SQUIRREL.

*Sciurus niger rufiventer* (Geoffroy).

*Sciurus rufiventer* Geoff., Cat. Mamm. Mus. d'Hist. Nat. Paris, 1803, p. 176.
*Sciurus ludovicianus* Custis, Barton's Med. and Phys. Journ., II., Pt. II., 1806, p. 47.

This species is found throughout the state where conditions are favorable. It is the commonest squirrel in the county, being apparently the only one now in a real state of nature. Its habitat includes all natural woodland where it is not persecuted, and it may be found in artificial groves and park areas if these are not occupied by the gray squirrel. It is said to prefer the open woods and edges of dense forests, while the deeper woods, the recesses of the swamps, and the heavily timbered river-bottoms are occupied by the gray squirrel. Beyond the state the fox-squirrel ranges from northern Louisiana to southern Wisconsin, and over the greater part of the Mississippi Valley, while the whole group included by Osgood under the specific name *niger*, is found from northern Florida to southern New York, its range on the south and west extending to central Texas and northeastern Mexico.

The length of such specimens from this state as are available indicates an average length of about 21 inches (530 mm.) with a tail of about 9.5 inches (240 mm.). This is somewhat less than the measurements usually given for the species. The series examined is too small, however, to determine local variations.

The dentition of the species is one incisor, one premolar, and three molars on each side above and below. This will serve to distinguish this species from *carolinensis*, in which there are two premolars on each side above in the adult.

But little has been added to our knowledge of the natural history of our squirrels since the observations of Kennicott, and the most that we can say is derived from his account.

They are inclined to be solitary in their habits, more than two adults being seldom found living together, and a pair remaining together only during winter and spring. The young are from two to four in number. Kennicott says that probably two litters are born each year, but it is difficult to reconcile this statement with others he makes. Probably a single litter in March or April is all that is produced. The young are "ugly unsymmetrical little things at first, with monstrous heads and closed eyes; and it is some time before they acquire the elegant proportions and agile movements of their parents."

Squirrels are very fond of corn, especially when it is green or newly ripened. In corn fields near extensive woodlands one often finds traces of their work. The ears of corn are either partly eaten on the stalk or carried to a neighboring fence or log and eaten. In early days, when their numbers were much greater than at present, squirrels became a veritable pest at times; but now their numbers are so reduced that there is little to fear from them. Both this species and the gray squirrel are great destroyers of birds' nests, and thus indirectly do considerable harm. Woodpeckers and other birds nesting in hollow trees seem especially liable to suffer from them.

The fox-squirrel is used for food, and probably the most of this species and the gray squirrel which are killed are so utilized. In early times they were sold in large quantities in the city markets of the state, and after the disappearance of the deer furnished an important part of the fresh meat eaten by the settlers, being perhaps even better appreciated than they are now.

The winter nests and permanent homes of the fox-squirrel are in hollow trees, and the same nest is said to be occupied by a pair for several successive seasons. Temporary nests are built of leaves and twigs in trees. These are apparently used for only a short time, and although usually at considerable height, I have seen them at an elevation of not more than twenty feet. Food for winter is stored up in large quantities in one place, but nuts, acorns, etc., are buried singly and dug up as needed. Apparently they do not truly hibernate, but are active all winter.

Squirrels are protected by the game laws of the state from November 15 to June 1, but undoubtedly many are killed during the closed season. It is especially to be regretted that they should be shot in the spring during the breeding season, when the helpless young must perish also. Within the county limits it is doubtful if there is any enemy to compare with man in their destruction, though a few are killed by the larger hawks and owls.

I fail to find any record of extensive migrations of this species such as have been so often observed in the case of the gray squirrel.

There must be, however, considerable movements of individuals and couples from place to place. Any place suitable for them they are sure to occupy in a short time if they are not molested.

The fox-squirrel is said not to make so engaging a pet as the gray squirrel, nor does it take so readily to living in the immediate vicinity of man.

### GRAY SQUIRREL.

*Sciurus carolinensis* Gmelin.

(Syst. Nat., I., 1788, p. 148.)

### NORTHERN GRAY SQUIRREL.

*Sciurus carolinensis leucotis* (Gapper).

*Sciurus leucotis* Gapper, Zool. Journ., V., 1830, p. 206.

The gray and the northern gray squirrels are probably both present in the state. They are closely related and have often been confused. Probably intermediate forms occur in this part of the country.

Both these gray squirrels are smaller than the fox-squirrel, have less of the rufous color, and are also distinguished from it by the dentition. While the fox-squirrels have but five teeth on each side in the upper jaw, the adult gray squirrels have in addition another small premolar, making six teeth on each side above. The average length of the gray squirrel is about 18 inches (450 mm.) and that of the northern gray squirrel is about 20 inches (500 mm.). The color of the northern subspecies is given as silvery gray above with under parts white, sometimes rusty on neck or chest. The gray squirrel is dark yellowish, rusty above, the under parts being white.

The habits of the two species are essentially alike, and the following account will apply to both.

The various subspecies of the gray squirrel are distributed throughout the United States east of the great plains, and are found as far north as southern Canada. The southern limit of the subspecies *leucotis* may be indicated by a line extending from the Catskills south of Pennsylvania in the Alleghany Mountains, and thence west through northern Indiana and Illinois.

Under natural conditions this species chooses wooded swamps and river-bottoms, with heavy timber, rather than the edges of the wooded bluffs and the groves—which are the commonest habitat of the fox-squirrel. Nevertheless, it is the gray rather than the fox-squirrel that is most often semi-domesticated in the parks of cities and the shady streets of towns. A general opinion of both squirrel hunters and other observers of more scientific pretensions seems to be that the gray squirrel, though smaller than the fox-squirrel, drives that species away from such territory as it chooses to occupy itself. Originally this species, like the fox-squirrel, was exceedingly abundant, and at times inflicted great injury on the crops of the farmer. At present, in this part of the country gray squirrels in a truly wild state are very uncommon. In fact, I have no record of one's being seen in the county for a number of years, though there are a few in the adjoining counties. This can hardly be due alone to the thinning of the thick woods. It seems more likely that their gregarious habit has been with them, as with so many other animals, a reason for their rapid destruction by man. The gray squirrel is said to be more prolific than the fox-squirrel, four to six being brought forth in one litter, and at least two litters being produced in a year. I have no proof of more than a single litter.

The most interesting characteristic of these squirrels is the readiness with which they become wonted to parks and the shaded streets of villages where they are not molested. They soon become exceedingly tame, often so much so as to feed from the hand of a stranger, and to enter houses by open windows, even venturing into rooms occupied by persons. They store up, under these circumstances at least, a supply of nuts or other food. Considerable quantities are often found hidden by them in garrets and outbuildings; but they also hide single nuts, etc., under leaves or in the ground, and during the winter may be seen looking for them.

Although they may be seen at any time during the winter if the weather is fine, yet in continued severe weather they do not appear, and presumably are partly torpid and fasting.

The early observers nearly all speak of the extensive migrations of the species in various sections of the country. These migrations usually occurred in the fall. Large numbers would congregate in a locality and then move off in one direction—not indeed in a continuous flock, but rather as individuals, stopping to feed or loiter for some time in a place, but yet moving soon, and always in the one general direction. In these migrations they seemed to be possessed by the same abnormal disregard of impediments as the lemmings. Though usually averse to taking to water, they would not at such times stop at rivers even though as large as the Ohio or Niagara, and vast numbers were drowned in their efforts to swim across. Although no such migrations of the species have been noticed of late years—owing probably to its diminished numbers—nevertheless the abundance of these squirrels in a given locality at different seasons has been observed to be extremely variable, and it is more than likely that such mass movements do take place though they are not so easily observed as formerly.

The economic status of the gray squirrel is in general the same in all respects as that of the fox-squirrel. Owing to its scarcity in this vicinity it is even more worthy of consideration when in a wild state. In cities and towns, however, when exceedingly numerous, its destruction of birds' nests may call for repressive measures. In such cases a due balance of nature may easily be regained, for the squirrels are easily killed, and there are many who are too glad to do it.

### RED SQUIRREL; CHICKAREE.

*Sciurus hudsonicus loquax* Bangs.

(Proc. Biol. Soc. Wash., X., 1896, p. 161.)

The red squirrel, or chickaree, is not found within the limits of Champaign county. It is said to occur at Onarga, in Iroquois county. It was probably introduced there, but is native in the northern part of the state. Kennicott says that it is found sparingly in heavy timber in Illinois but not in the southern part. We have no data by which to determine the southern limit of its range.

### CHIPMUNK.

*Tamias striatus lysteri* (Richardson).

*Sciurus* (*Tamias*) *lysteri* Rich., Faun. Bor. Amer., Mamm., I., 1829, p. 181, Pl. 15.

The striped chipmunk (*Tamias striatus*) is found north to New Brunswick and Ontario, west to southern Michigan and Wisconsin, and south to Georgia, Alabama, and Florida, but it is not found on the Atlantic coast plains. It occurs as far west as Kansas, Missouri, and Minnesota. Over this area it is divided into several subspecies.

The average size of the chipmunk is about as follows: Total length, 9.75 in. (250 mm.); length of tail, 4 in. (100 mm.); hind foot, 1.4 in. (36 mm.).

The color of specimens taken in Champaign county is as follows: Hair on chin, throat, belly, and inside of legs creamy white, faintly flushed with buff near the borders. In a small spot behind the ears the hair is dirty white throughout its length. A streak below the eye and one above are buff to the base. The hairs on the under side of the tail are entirely chestnut. On all the other parts the hairs are all plumbeous at base. Over the side of the body the dark base of the hairs is followed by a broad band of buff with usually a minute tip of black, a few of the hairs having broad black tips. Over the rump, the outside of the hind legs, the top of the head, the front of the ears, and in a stripe back of the eye the buff is largely replaced by chestnut or bay. On each side of the body there is a light stripe extending from shoulder to rump. Here few of the hairs have black tips, but, instead, very light buff or creamy white ones. Each side of the light line is a dark one, all the hairs of which are black-tipped. These dark lines are each obscurely banded with a slender line of hairs tipped with chestnut. There is a vertebral line of black-tipped hairs bordered with chestnut-tipped ones, these being continued forward as a faint line which is lost in the chestnut of the top of the head. In the space between the vertebral line and the series of light and dark lines on each side, the hairs are annulated with black and white or light buff, the general effect being a dark gray. The hairs on the upper surface of the tail are banded with plumbeous, chestnut, and black, with a tip of light buff, the general effect being a brownish gray.

The incisor teeth are pale chestnut. The palms are naked and white. The soles of the hind feet are hairy and dark gray.

Chipmunks are not found in the open prairie and are but seldom seen in closely pastured woodland or in prairie groves. The wooded bluffs, and the bottoms down to the usual high-water mark, are their common habitat. They are not often found in the deeper woods, but rather along the edge of the bluff woods, where the trees have been thinned out but where there is still an abundance of old logs, bushes, and brush-heaps. Where the proper conditions exist they are quite numerous, but over a large part of the county they are rare or entirely wanting.

The chipmunk of this part of the country differs strikingly from the New England representative in two respects. In the first place it is far more independent of any such shelter as logs, stones, fences, etc., in choosing a place for its burrow. This is often found in an open spot so near the border of the woods that its owner is a near neighbor to the striped gopher. Then, too, our chipmunk takes to a tree more readily and climbs far more daringly than the eastern one does. Though I have never seen one attempt a leap from branch to branch, it climbs readily to a height of thirty or forty feet, and seems quite at home on the trunk and larger branches, showing none of that uneasiness which Merriam attributes to the chipmunk of the Adirondacks when treed.

I have seen chipmunks pass in and out of holes in hollow trees at a considerable elevation, but have no proof that such cavities were used either for nests or storehouses. The nests are usually at the end of burrows six or ten feet in length, running diagonally down to a depth of two or three feet. If the nest is under a log, stump, or other shelter, the depth may be less. At first the burrows are quite simple, but, later, accessory runways are dug leading to various chambers used as storehouses. Chipmunks are social, a number living together in the same nest.

The food of the chipmunk is largely nuts, acorns, and various small seeds—including corn and grain. It also eats fungi, and is exceedingly fond of berries and other juicy fruits. I find no record of its eating insects or other animal food, but it is a remarkable exception to the other squirrels if it does not do so. It stores up food for winter in underground cavities, and often in surprisingly large quantities. Kennicott took over half a bushel of hickory-nuts and acorns from one such storehouse. It has also been observed to bury stores in a manner similar to that of the other squirrels.

In spite of abundant supplies chipmunks have been found in a semi-torpid condition during the winter. On the other hand, they have been seen abroad by various observers even in severe weather, when there was snow on the ground. Probably the winter sleep is never so deep and so long continued as is the case with the woodchuck or other truly hibernating animals.

Chipmunks, although not rare, are by no means so plentiful in the county as in rougher portions of the country. Undoubtedly the lack of protection afforded by rocks, stone walls, rail fences, etc., has something to do with their scarcity. Their enemies are many. Although not used as food they are nevertheless victims of the boy or the bumpkin with a gun. Many are taken by the larger hawks, and cats, weasels, and snakes all help to keep the number down. Being largely day-feeders, it is not likely that night-prowlers catch many of them, though their remains have been found within the stomach of the common screech-owl.

The chipmunk's actions show the result of many generations of constant peril; and if Burroughs's statement that he is never more than a jump from home be a poetic hyperbole, it is true that he is seldom more than one jump from some kind of shelter. In collecting his food or in his play, he moves by fits and starts from one post of observation to another. His curiosity is quite equal to his timidity, however, and though he scampers into his hole at the least sound or sign of a suspicious object, he is pretty sure to peep out in a moment, and the boy with a stone or gun knows that he has only to wait a minute for a chance to throw or shoot.

In the vicinity of cultivated fields a considerable part of the food consists of corn and small grain, with occasional meals of berries or larger fruit; but the real loss sustained by the farmer is very little, for the grain taken is almost entirely waste, gleaned by the industrious little fellow. If chipmunks should become so numerous as to be a pest they are easily trapped, poisoned, or shot. There seems, however, little danger of that in this county, and it seems a pity they might not be left unmolested.

### STRIPED GOPHER; THIRTEEN-STRIPED SPERMOPHILE.

*Citellus tridecemlineatus* (Mitchill).

*Sciurus tridecemlineatus* (*sic*) Mitch., London Med. Repos., N. S., 1821, p. 248.
*Spermophilus tridecemlineatus* of Kennicott and various authors.

This little animal is often called the striped prairie-squirrel, and scientists usually prefer the term striped spermophile, since the word "gopher" has been applied to quite a different animal; but the name striped gopher is most generally used and best understood. The term thirteen-striped designates the most striking feature of its appearance. The stripes are made up of six narrow lines of dirty yellowish white alternating with seven broader dark ones, clove-brown in color. These dark stripes are marked by a row of light spots in the middle. Sometimes—especially in the two outermost dark bands—these light spots run together, dividing the broad dark stripe into two narrow ones. The striped gopher is often confused with the chipmunk, but the slightest attention to these markings is sufficient to distinguish them.

The average size of specimens from Champaign county is as follows: Length, 10.9 in. (277 mm.); tail, 3.62 in. (92 mm.); hind foot, 1.5 in. (38 mm.). This is larger than the measurements usually given. The series measured, however, is a small one.

The gophers are all animals of the open country, avoiding timber, not climbing trees, but seeking refuge in burrows. The range of the striped gopher, under various subspecific names, corresponds in general with the prairie region of North America. In Michigan, Wisconsin, and Minnesota the clearing of the land has brought about prairie conditions, and the species has pushed north beyond the original prairie. The same is true, to some extent, of other directions.

The habitat of this species is always the open. Practically it is never found in woodland, and but rarely in fresh pasture or recently cleared land. On the other hand, it is, within the county, not partial to the extreme prairie type or the till plains, but is far more abundant along the moraine ridges and the portions of the bluff areas that have been long cleared and in pasture. Undoubtedly the area of favorable habitat within the county has greatly increased since its settlement. The species is found in the till plains, especially in localities not under continuous cultivation. Such areas, however, are chiefly limited to borders of fields and a few small pasture-lots. It soon enters a field left down in grass, and also the margins of corn and grain fields. It is rarely found in the middle of such fields. It is found in the cleared pasture also, especially near cultivated fields, but is most abundant in pasture-lots along the crests of the moraines. Here it may be found any summer day so long as the sun is shining.

Like most other non-combative animals living in the open, the striped gopher is exceedingly nervous and timid. The whole existence of these animals above ground seems to be passed in deadly fear of enemies that soar in the air above or lurk in the grass around them. As they creep through the grass they pause every few feet and sit up to look and listen; they crouch low at every passing shadow, and jump suddenly sidewise, backward, or forwards, as the case may seem to require, from the slightest rustling near them. Of course in reality these actions are for the most part unconscious reactions, their existence requiring, after all, no more watchfulness and dodging than a man must exercise or do in the crowded streets of a great city.

The curiosity of the animal is quite as characteristic as its timidity. Sitting bolt upright at the mouth of its burrow, it will watch an intruder till some noise or motion sets off its unstable reflexes, when it dives into its hole with what seems a half shriek, half chatter of terror. But in a moment it emerges to investigate, and perhaps to repeat the performance. Boys take advantage of this habit of the striped gopher to catch it with a slip-noose. The noose is laid over the mouth of the burrow into which a gopher has just been driven, and with the cord bearing the slip-knot in his hand the boy lies down a few feet away, usually not having to wait long before the gopher puts its head through the noose and is caught.

The young are born about the first of June. The period of gestation is about one month. Lee found the number of embryos in 129 pregnant females varying from 5 to 13, the average being 8.5. The number in a single horn of the uterus varied from 0 to 9. The young are born in an undeveloped condition, and are hairless for about three weeks.

In spite of the remarkable fertility of this species, it does not increase to any great extent in this locality. Its enemies are many. Probably in this county the most important ones are the hawks. Skunks and weasels also kill them, and the fox undoubtedly takes them when nothing more acceptable offers.

I have never been able to detect a striped gopher abroad during the night, though I have spent many hours watching for them. A specimen kept in captivity in a living room could be heard at night stirring in its cage and eating. It may perhaps take a lunch at night in its hole, but I think it does not come out during the middle of the night.

The species is undoubtedly quite dormant during the winter. A specimen kept in a cage in a rather overheated room all winter remained in a sleepy, stupid condition from about the first of November till the last of February. Apparently it partook of food sparingly—only two or three times during that period. For a month at least before and after these dates it was very stupid, stirring but little. At no time during the winter was it perfectly indifferent to touching, shaking, etc., but responded only by half opening its eyes and making a complaining or angry cry. It appeared to be half asleep, and, left alone, immediately fell into a dormant condition again. The temperature of the room was probably never below 60°, and often about 80°, all winter. Specimens dug out of the ground in midwinter are always fully dormant. In this latitude they remain holed in from October to March inclusive, and are seen but little for some weeks before and after that period.

The exact relation of the striped gopher to the farmer, whether on the whole it does more good or evil, seems to be by no means certain. Although its burrows are abundant at times, they are so small, and, being without accumulations of dirt around the mouth, so inconspicuous that they can do but little harm. Its food, as that of rodents in general, is chiefly of vegetable origin—seeds, buds, grains, and parts of plants of all kinds. The grain that it eats in the fall is probably largely gleanings and represents but little loss to the farmer, being more than compensated for by the seeds of weeds destroyed. A more serious accusation, however, brought against it is that of taking the newly planted corn in the spring. It sometimes follows along the rows of corn just as it is sprouting, eating the kernels and thus destroying the crop. Although a portion of this damage sometimes attributed to the gophers is in reality done by grackles and crows, nevertheless the gophers do considerable injury in that way. On the university farm I have found by actual count about twenty per cent. of the first two or three rows of corn along the side of a field taken by them. This field was next to a piece of land that had been in pasture for some time, and which contained many gophers.

But the gopher, like most of the rodents, is more or less carnivorous, or at least insectivorous. Gillette found as the result of an examination of twenty-two stomachs of gophers taken from April 19 to August 2 that forty-six per cent. of the contents was of insect origin. Some of these insects were predaceous beetles, and their destruction was a loss to the farmer; but there were a larger number of sod worms (*Crambus* larvæ) also found. The writer estimates that an average of twenty-six worms per day were eaten by each gopher between the above dates, or a total of 2730 worms for the season. Besides these a large number of grasshoppers, wireworms, and other injurious insects were destroyed.* Aldrich's report† on the examination of fifteen stomachs of gophers taken in South Dakota, although not quite so favorable still makes a good showing for the gophers in regard to the number of insects destroyed. I have repeatedly observed them hunting and eating insects. One that I watched, was sitting up eating a big fat grub, biting deep into the juicy, dripping, wriggling dainty, and licking his paws with true epicurean satisfaction when it was finished. There can be little doubt that in this immediate vicinity the good that they do, quite compensates for the damage they may cause.

Hoy found that specimens in captivity were carnivorous, and ate "meadow-mice, flying squirrels, and even their own young." This was undoubtedly due in part to abnormal conditions. White-footed mice and meadow-mice are usually associated with the gopher. I have found the prairie white-footed mouse and the gopher living together in such abundance that it is not easy to conceive of the gophers as habitually feeding on the mice.

If owing to their overabundance, or to other local conditions, the gophers become a pest, no animal is more easily gotten rid of. The readiest and cheapest way to exterminate them over a considerable area is to poison them. If the poison is put into the hole and reasonable care is taken, this may be done with but very little danger of poisoning other animals. They may also be killed by fumes of carbon bisulphid, and in the immediate vicinity of dwellings and barns this may be the most desirable way. They are easily trapped. Often their burrows are shallow, and they are easily drowned out by pouring water into their holes. Finally, the boy with a gun easily decimates them if given a chance.

### GRAY GOPHER; FRANKLIN'S SPERMOPHILE.

*Citellus franklinii* (Sabine).

*Arctomys franklinii* Sabine, Trans. Linn. Soc., 1822, p. 587, Pl. 27.
*Spermophilus franklinii* of Kennicott and various authors.

This species, often called the prairie gray squirrel, is found through the northern two-thirds of Illinois, northern Missouri, and

* Bull. Iowa Agr. Exper. Station, No. 6 (1888), p. 244.
† Bull. S. Dak. Agr. Exper. Station, No. 30, pp. 8–11.

eastern Kansas. Thence its range extends north through the valley of the Red River of the North and the Saskatchewan. It is also found in Indiana near the western boundary.

The gray gopher bears a superficial resemblance to the gray squirrel, but the habits of the two are totally different. The tail of the gopher is short, and the hair is sparse and coarse, with no soft under-fur.

The color of the young is as follows: Over the back the hairs are banded buff and black, the banding and arrangement giving the effect of light spots on a dark background; or the spots may be so large and so arranged as almost to form irregular transverse bars of light and dark. Over the head and neck many of the hairs are tipped with pure white, and the general effect is gray. Over the sides the general color is more rusty than on the back. The chin and throat are dirty white. On the belly and inside of the legs the color is dirty buff. The tip of the ear is black within. The inside of the ear and a strip around the eye are ochraceous. The whiskers are black; the claws, horn-color. The hairs of the tail have long, light tips, which are ochraceous at base and whitish near tip. In the older specimens the barring becomes more obscure, and the lighter colors become more rusty and more extensive. The last two-thirds of the tail is gray with a slight flush of ocher.

The total length is about 15.16 in. (385 mm.), the tail is 5.12 in. (130 mm.) long, and the hind foot 2.13 in. (54 mm.).

Early writers describe this gopher as inhabiting the edge of the woods or tracts dotted with low bushes, etc., rather than the open prairie. At present a necessary condition for their habitation seems to be the presence of some shelter, such as may be furnished by tall grass, or a field of clover, alfalfa, or grain. Others have noticed that when the crop on such a field is cut the gophers leave, at least for a while, and my own observations coincide with theirs, though I have known the gophers to return to the same spot after the second crop of alfalfa had started. They avoid closely cropped pastures, well-kept cemeteries, lawns, and similar places where the striped gopher is especially abundant, yet even in such localities I have found them congregated under a heap of compost. In fact such a shelter seems to have special attractions for them, as noted by Bailey. Kennicott says that they are less shy and less disturbed by cultivation of the land than the striped gopher. My own experience is that while they are perhaps more apt to take up their quarters in the immediate vicinity of barns and farmhouses, they are at the same time far more difficult to approach in the open. They are almost sure to move if the grass or other shelter over their burrows is cut, or if the ground is disturbed by cultivation. They are hence continually shifting their location, often returning to the same place after an absence of some weeks.

There is a common opinion in this vicinity that this species is driven off by the striped gopher. I have never seen the two species together, though very frequently colonies of each may be found within a few rods. I know of no proof as to which can drive off the other.

The species is decidedly gregarious, nearly always being found in colonies. As their burrows each have several openings and these are conspicuously marked by the dirt thrown out, a colony becomes a great nuisance in a hay or grain field. The conspicuousness of these burrows and of the animals themselves has aroused the animosity of the farmers and hastened the destruction of the gophers.

My own data are too incomplete for absolute proof, but I am inclined to believe that a census of the gray gophers in the county would show their abundance in the different habitats to be in the following descending order: moraine bluff, till plain, and cleared pasture. I have never seen them elsewhere, though I presume that they may be found in the borders of woodlands.

The food is largely vegetable, consisting of grain, seeds, and other vegetable matter. The exact nature of this part of the food will of course vary with the habitat, but may be quite largely grain. Bailey, as the result of an examination of twenty-nine stomachs, found that over thirty per cent. of the food was animal matter—largely insects. They are known to kill birds, young chickens, and small mammals, and even gray gopher hair has been found in the stomach.*

They store up grain and seeds for winter, as much as half a peck of oats having been found in a burrow under a shock in September. It seems certain, however, that they hibernate during the middle of winter. They are seldom seen here after October or earlier than

* The Prairie Ground-Squirrels, or Spermophiles, of the Mississippi Valley. Bull. No. 4, Div. Orn. and Mamm., U. S. Dept. Agr., pp. 56, 57.

April. A specimen kept in captivity by Baird did not hibernate, but many other observers have found them quite dormant in winter. Probably the depth and duration of the winter sleep varies with locality and circumstances. They have been known to ascend trees, but such feats are very rare.

Early writers speak of these gophers as being not at all shy. Possibly persecution has made them cautious. They are certainly not easily approached in this vicinity. They are said, however, to be easily tamed in captivity.

Exact and numerous records of the number of young, time of birth, and period of pregnancy are wanting, but so far as available observations go, they indicate that there is one litter a year and that this is smaller than in the case of the striped gopher, containing about four to eight young. They are born in early spring, and remain with the parents during the summer and probably till the next year.

Specimens taken August 9 had reached a total length of 10.5 in. (268 mm.).

In this county the species is seldom abundant enough to constitute a serious economic problem. Compared with the striped gopher it does more damage by eating grain and by covering grain, clover, etc., with the dirt from its burrows. Its burrows, being larger, constitute a disfigurement, and are an annoyance to horses, whose feet may catch in them. There is also a small amount of poultry and eggs charged to their account; but these losses seldom amount to much, while considerable benefit must result from their destruction of insects, especially grasshoppers. In general we believe that the good they do quite balances the harm.

In case they should become a pest they are easily gotten rid of by poisoning, or by any of the other methods applicable to the striped gopher.

Their natural enemies are the larger species of hawks, and skunks and weasels. Cats kill some of them, and a few are killed by man. Like so many other rodents their number in any locality is apt to vary greatly from year to year. This is apparently due to migrations rather than to uneven mortality.

There seems no reason except prejudice why the flesh of this gopher should not be used for food as well as that of the various tree-squirrels. Its food is as clean and its habits are as neat.

## WOODCHUCK; GROUND-HOG.

*Marmota monax* (Linnæus).

*Mus monax* Linn., Syst. Nat., I., 1758, p. 60.
*Arctomys monax* of Kennicott and many authors.

The woodchuck is found from Georgia, Alabama, and Kansas north to Hudson Bay and westward to the Rocky Mountains in the northern part of its range, but is not usually at all common in a prairie country. It is rare in this county except in the extreme northern part, where it is said to be not uncommon.

The woodchuck is a thick-set, clumsy animal, with legs so short that the gait resembles that of a fat pig. It is about 22 in. (560 mm.) long, the tail, which is sparingly bushy, being approximately 4 in. (100 mm.) in length. The ears are short. The usual color of the back is grizzly brown, with head, tail, and feet darker; the belly is rusty reddish. Individuals vary greatly, however, some being nearly black, while the light-tipped hair of others gives the animal a light grayish yellow color.

The woodchuck loves a rolling country with a light soil and an abundance of clover, grass, and grain. Given these, woodchucks will more than hold their own with civilization. Through many parts of New England and the Middle States they are probably more abundant now than when the country was first settled. Kennicott, writing of northern Illinois in 1856, says that the woodchuck "was exceedingly rare ten years ago but is now becoming quite common. It is an inhabitant of the woods. I am not aware that it ever lives in the prairie". I found it abundant in McHenry county, and it is said to be equally so in the adjoining counties. It is not now, however, so much an "inhabitant of the woods" as of the cultivated fields where woods stood when Kennicott wrote this. Woodchucks seem never to have been abundant in Champaign county, and at present there are only a few here, these occurring along the borders of the wooded bluffs.

These animals are believed to be strictly vegetarian in their diet.

Their burrows are extensive, and always conspicuous on account of the large quantities of earth thrown out. They do not hesitate to swim across bodies of water, and they do it easily. They have been known to climb low or slanting trees, but this is not usual.

Their young are born in one litter of four to six, in spring. Their winter sleep is profound, and lasts in New England from about the middle of September to the middle of March. It is probably of somewhat shorter duration here. Like the striped and gray gophers, they sit erect when watching for enemies, and whistle shrilly when alarmed.

The woodchuck is often kept in confinement, but it is a rather stupid and uninteresting pet.

I do not know of any way in which a live woodchuck can be of service to man. The flesh is often eaten by those who like coarse game, and the skin makes a tough leather of limited use. Where woodchucks are abundant they are a serious pest in meadows and grain fields. They beat down the crops, thus rendering harvesting difficult, and the earth they throw out injures the mower or reaper. Their burrows may be stepped into by horses or cattle, and for this reason may be counted dangerous. However, woodchucks are readily gotten rid of. They may be taken in a steel trap set in the mouth of their burrows, or they may be easily poisoned with carbon bisulphid. Moreover, they furnish an excellent mark for practice in rifle-shooting.

### FLYING SQUIRREL.

*Sciuropterus volans* (Linnæus).

*Mus volans* Linn., Syst. Nat., I., 1758, p. 63.
*Pteromys volucella* of Kennicott and various authors.

The general range of the flying squirrel is from northern New York south to Florida and west to the plains.

The size of Illinois specimens is about as follows: Total length, 7.8 in. (200 mm.); length of tail, 3.25 in. (83 mm.); length of hind foot, 1.2 in. (30 mm.).

The color above is drab shaded with russet, the base of the hairs being plumbeous; the tail is slightly darker above, beneath buffy gray; the hands, above, are grayish white; and the feet are drab. There is an orbital ring of brownish black and a broad band of the same at the edge of the wing-membrane. The under parts are white, washed with yellow or buff.

The tail is densely clothed with soft hairs, the whole being smoothly flattened, though the vertebræ are of normal form. The eyes are dark and large; the ears, nearly naked and rather large and rounded.

It "flies," in long sailing leaps, by means of an extension of a fold of skin along each side of the body and the neck. There are two parts to this parachute. The larger part extends between the fore and hind limbs, and is held taut by a cartilaginous rod extending from the wrist backward, between the folds of skin, and also by specially developed dermal muscles. The other membrane fills the triangular space between the fore limb and the neck and side of the head. This is held taut by muscles, the chief one of which arises from the zymotic arch and is attached to the rudimentary thumb.

The flying squirrel can not be mistaken for anything else. Of all the mammals found in the county, none is more beautiful or interesting, and yet, considering its abundance, none is perhaps so little known. This is due chiefly to the fact that it is among the most strictly nocturnal of animals—quite as much so as bats or owls—and is, moreover, so quiet and inconspicuous in its movements that it is seldom seen. A nest may remain undiscovered by the passers-by even in a much frequented locality. On the other hand, as there are usually a number of animals in the same nest, the ordinary observer who finds a colony by accident is quite sure to have an exaggerated idea of their abundance. For this reason little reliance is to be placed on popular report of their numbers. I have obtained but few reports and observations concerning the presence of the species in the county; nevertheless, considering how nearly the individuals I have observed escaped detection, I am of the opinion that flying squirrels may be said to be fairly abundant even in the neighborhood of Urbana and Champaign.

Kennicott and the majority of early observers mention deep woods or large groves as the habitat of this species. I have never known of their being found in the groves scattered over the prairie, but they occur in the large woods and in the little clumps of trees that represent the ragged fringing remnant of the wooded-bluff region. Here they are found, several together, nesting in hollow trees.* In other parts of the country they build nests of leaves lined with softer material; or, more rarely, they build them entirely of such softer substances as grass, fine bark, etc. I have no record, however, of such nests within Champaign county, or even within

* I have run as many as fifty out of one den.—Dr. J. Schneck, 1886, Mt. Carmel, Ill.

the state. They also enter houses, dove-cots, etc., and build their nests there.

The food of the flying squirrel includes the usual wide variety of substances eaten by other squirrels—seeds, nuts, buds, etc., and, at least in captivity, beetles and raw flesh. Probably birds and nestlings are sometimes eaten by it.

This species is the most exclusively arboreal mammal we have, never straying far from trees, seldom touching the ground, and never, so far as observation goes, making long runs on the ground or even following fences for any considerable distance. During the winter it keeps to the nest and is more or less torpid. It lays up stores, however, and in captivity is somewhat active during the winter, though it is said to be dull and stupid, lacking entirely the vivacity that characterizes it in summer.

The females are said to produce a single annual litter in April in the northern part of their range, but as many as three litters a year in the South. Data on this point for this county are too meager to be of value. The number in a litter is from three to six.

These squirrels may be said to be gregarious but not social. The family remains together for a considerable time, and possibly others join it. At least quite large colonies are found living in the same tree. They are not quarrelsome, but in their work and their play they exhibit a remarkable indifference to each others' presence, each sporting by himself without regard to the others. The mothers, however, show remarkable devotion to their young.

Nothing can be more elusive than the flight of this squirrel when first seen. Even if the eye is fortunate enough to note the start, as the squirrel leaps from a tree in a long, swift, silent glide, the quick upward turn is sure to bewilder and make one lose sight of the animal. There is a striking resemblance between this quiet gliding downward of the squirrel and the floating of a leaf. There is said to be a slight tremulous motion of the fore limbs during the glide, but it is difficult to see what function this may have in the movement of the animal.

The flying squirrel has three quite diverse calls or cries. It utters the usual "chuck-chuck" of squirrels, the usual quick, sharp squeak when scolding, and also, more rarely, a clear musical note, commonly melodious and pleasant, but occasionally shrill. This resembles the chirp of a bird, and may be kept up for ten minutes at a time.

This squirrel is one of the most easily tamed of all our wild animals, none of which are more gentle and interesting. The captive may usually be trusted to run about the room without making any effort to escape. However, if given too much liberty, according to my experience, some day, with no apparent reason and when least expected, there is a dash for liberty, and the squirrel is gone for good. The playfulness of these little animals, their gentle, graceful beauty, and their wonderful vivacity make them most delightful pets.

### BEAVER.

*Castor canadensis* Kuhl.

(Beit. Zool., 1820, p. 64.)

The beaver seems to have been practically exterminated in this part of the state before the first permanent settlers came. There was an extensive dam on the South Fork a few miles above Urbana, and several others, less generally known, on the lower part of the Salt Fork. There is probably not a wild beaver in the state at the present time.

### BLACK RAT.

*Mus rattus* Linnæus.

(Syst. Nat., I., 1758, p. 61.)

The black rat is mentioned by early travelers as existing in the river towns in the southern part of the state. It is extinct at present so far as known.

### BROWN RAT; NORWAY RAT.

*Mus norvegicus* Erxleben.

(Syst. Regn. Anim., I., 1777, p. 381.)

*Mus decumanus* Pallas, Nov. Sp. Quad. Glir., 1778, p. 91.

This is the only species of rat found in the county, and probably the only one now in the state. Like the house-mouse, it has become cosmopolitan. I have never myself seen the animals or identified their burrows in open fields, borders of woods, etc., except in the immediate vicinity of some extensive artificial shelter, such as a compost heap, straw stack, or the like. Undoubtedly there are individuals leading a wild life, but they can not be abundant. There have been instances of rats' becoming so abundant in the fields as to be a decided pest. For example, in the summer of 1903 immense numbers appeared in several counties of western Illinois, especially in Mercer and Rock Island counties, and were a veritable plague during that and the following year.* I have never heard of a similar visitation in this county. It is pretty well established, however, that the appearance of vast numbers in a locality where they have not been known to be excessively abundant before is due to continued conditions favorable to the increase of the species, and is therefore liable to occur in any locality where the species is fairly abundant.

Rats are exceedingly fertile. They breed three to five times a year, and a litter varies in numbers from six to twenty. The period of gestation is twenty-one days. A female rat can breed when less than three months old.* The young are brought forth in a very undeveloped condition, being hairless, with eyes closed and the outer ears glued down over the orifice.

The rate of reproduction varies with the climate and the food supply, a moderate temperature and an abundance of food increasing both the number of litters a year and their size. Extensive investigations made in connection with the United States Biological Survey indicate that the average for well-fed individuals in this latitude can not be less than ten to a litter. At this rate, supposing there were only three litters a year, if a single pair and their progeny should breed uninterruptedly for three years, and no deaths occur, the total number resulting would be something over 20,000,000 individuals.

There is no mammal in the state against which so much that is injurious can be proven, and for which so little of good can be claimed; and the whole economic problem so far as the rat is concerned, reduces itself to determining how to exterminate it most rapidly and satisfactorily. Since, in spite of their great fertility, rats are not increasing rapidly, it is evident that there must be many agents naturally tending to their destruction, for very few of them, comparatively, are killed by man under ordinary circumstances.

* Lantz, D. E. "The Brown Rat in the United States." Bull. No. 33, Biol. Surv. U. S. Dept. Agr., p. 17.

Of all these natural enemies the weasel is probably the most destructive. This little carnivore seems to have taken upon itself the regulation of overproduction among all the *Rodentia*. Skunks and foxes also make way with many of them. The larger owls kill many rats, and are probably responsible for killing more of them than any other animal except the weasel. The larger hawks also catch them occasionally, and are undoubtedly an important factor in checking any overabundance of rats in the fields.

Although comparatively rare in the fields, the damage done within the county by rats in the immediate vicinity of man's abode must amount to many thousand dollars each year. The heaviest loss is probably in granaries, elevators, and various other storehouses for grain or for flour or vegetables. They are very destructive to young poultry. Probably no small part of the loss of this kind commonly attributed to weasels and skunks is due to rats. They are also great thieves of eggs.

Of late, attention has been called to the fact that destruction of property by rats is the least important of their evil deeds. Far more serious is their agency in the spreading of infectious disease. The bubonic plague is spread entirely by means of the rat flea. Trichinosis among swine is perpetuated, so far as is known, entirely by rats. Trichinæ can only occur in hogs as a result of their eating the flesh of some infected animal, and the rat is the only other animal with which the hog comes in contact that is so infected. As they frequent in turn sewers, outhouses, granaries, storehouses, and pantries, they may also disseminate such diseases as typhoid, dysentery, and tuberculosis.

## HOUSE-MOUSE.

*Mus musculus* Linnæus.

(Syst. Nat., I., 1758, p. 62.)

The common house-mouse has followed the European races of man into all parts of the globe. So far back as the time of Kennicott's papers on the mammals of Illinois (1856–1857) it had become frequent in the fields, digging burrows and laying up stores in them. It is very abundant in harvest fields in late summer and fall, often far outnumbering all the other species of small mammals taken together. At that time traps set inside shocks of grain or corn will often catch but little else. There seems to be an irruption of these mice into the field after the crop is cut. Traps set under shocks just put up will catch none of the mice, except perhaps near a barn or other shelter, but later the mice may be taken under shocks farther and farther out in the field, and within a fortnight they may be found in the center of an eighty-acre lot. As noted on page 505, they apparently drive the white-footed prairie-mouse away from the shocks. During most of the year house-mice are not commonly found in the woods or open fields except under some sort of artificial shelter. It is curious to note how a refuse dump, a compost heap, a pile of old boards, a haystack—whatever is the work of man's hands or the remains or refuse of his habitations—attracts these mice. In the middle of an extensive sand area in Mason county a few bits of boards and a bushel or two of old tin cans and broken pottery gave shelter to a colony of house-mice, though a full half mile from anything else that could have protected them. Bailey reports finding them in Texas on a deserted ranch a hundred miles from the nearest railroad town.*

There is considerable variation in color in this species within the county. The general mouse-gray is usually modified to a greater or less degree by a flush of orange-yellow—"varying through smoke-gray and drab-buff to near orange-buff." One gets all these variations in a single locality and among specimens taken on the same date. I have not been able to correlate these variations with any ecological factor.

### WHITE-FOOTED WOOD-MOUSE.

*Peromyscus leucopus noveboracensis* (Fischer).

(Osgood, N. Am. Fauna, No. 28, 1909, p. 117.)

*Mus sylvaticus noveboracensis* Fischer, Synop. Mamm., 1829, p. 318.
*Mus leucopus* (Raf.), Kennicott.

The range of this subspecies is from Nova Scotia to central Minnesota, thence south through the humid parts of eastern Nebraska and Kansas, and eastward to the Atlantic coast.

There is considerable variation in size, as shown by the following table.

* N. Am. Fauna, No. 25, p. 92.

| No. of specimens measured and places of capture | Average length | | | | | | | | Ratio of length of tail to length of head and body |
|---|---|---|---|---|---|---|---|---|---|
| | Total | | Head and body | | Tail | | Hind foot | | |
| | in. | mm. | in. | mm. | in. | mm. | in. | mm. | |
| 178, whole state. . | 6.42 | 163.8 | 3.56 | 90.3 | 2.89 | 73.5 | .79 | 20 | 80.3 |
| 96, Champaign Co. | 6.53 | 165.7 | 3.55 | 90.2 | 2.97 | 75.5 | .79 | 20 | 83 |
| 28, Olive Branch, southern Ill . . . . | 6.11 | 155.3 | 3.43 | 87.2 | 2.68 | 68.1 | .79 | 20 | 78 |

This table indicates that the specimens from the southern part of the state are rather smaller, and their tails both absolutely and comparatively shorter, than those from this county. The specimens from Olive Branch were all taken the last week of December and the first of January.

The color varies with the age and the condition of the coat. In all specimens, however, the hairs of the feet and chin are white to the base. Very rarely a few dark hairs are found below the wrist or ankle. The hairs on the belly, throat, and inside of the legs are white except for the plumbeous base. In immature individuals the general color on the sides is hair-brown slightly warmed with ochraceous. Toward the dorsal line this becomes darker, being nearly blackish slate over the back. This coloration is often quite indistinguishable from that of the white-footed prairie-mouse. In the brightest-colored mature forms the majority of the hairs on the upper parts are tipped with warm ochraceous buff, but mingled with these are black-tipped ones, producing the general effect of Vandyke brown over the back, while the sides are paler. All shades possible between these brighter hues and the general color of immature specimens may be found among adults. Part of this variation is probably due to the fact that the ochraceous tips of the hair fade or wear off as the pelage becomes shorter. The tail is usually bicolor—mouse-gray to dark sepia above, white below. The ears are large, thin, and dusky except at the margin, which is very narrowly bordered with white.

This species is very similar to the white-footed prairie-mouse, but is larger, the feet pure white, no black hairs occurring on them, and the tail is longer than that of the prairie white-foot. The length of the tail vertebræ divided by the length from the tip of the nose to the base of the tail gives a ratio that will serve to distinguish the two species. This ratio is .7, or over (usually .75 to .9), for the woodland white-foot, and under .7 (usually .6 to .65) for the white-footed mouse of the prairie.

The common name of this mouse is especially appropriate, as the habitat of the species is practically coextensive with the woodland areas of the state, present or past. I have taken it in a clump of bushes, hardly three rods square, standing alone in the prairie some miles from any timber, but I do not often find it following fences or hedges unless these are near areas recently wooded, and it does not usually make its nests or burrows where there is no shelter.

I give below the per cent. of specimens taken in the different habitats in this part of the state.

| | | | |
|---|---|---|---|
| Till plains, | 5 per cent. | Flood-plain, | 35 per cent. |
| Moraines, | 4 per cent. | Groves, | 33 per cent. |
| Bluffs, | 13 per cent. | Cleared pasture, | 10 per cent. |

These figures indicate in a general way the relative abundance of the species in the different situations. As much more trapping was done on till plains and moraines than in the other localities, the percentages given for those two are too high to denote relative abundance. In the fall and winter I find this species in the deepest woods still standing in the county. I have also found it in heavy timber of beech, maple, and oak on the hills in the southern part of the state. During summer these mice leave the thick woods and are found along the borders of woodlands; in pastures where there are stumps, brush, or other shelter; and especially along the margins of brooks and on flood-plains. They are not found on till plains or moraines except in the neighborhood of timber or where there is a clump of bushes or similar shelter. Shocks of corn or grain near groves or other woodland may be occupied by them.

This species and the prairie white-foot, though often found within a short distance of each other, do not mingle. I have taken the house-mouse and woodland white-foot under the same pile of boards; and the house-mouse and the white-footed prairie-mouse under the same corn shock; but I have never found the prairie-mouse and the woodland one living together in such manner.

This mouse usually builds its nest under stumps, logs, or similar cover. Its burrows are little more than passageways under such cover, lying, at most, but a few inches under ground. I have never found a burrow of this species in the open without protection. Occasionally the nest is made in a wood-pile, or in an old stub or tree some feet from the ground. I saw one in a decaying apple-tree four feet above the ground. Hoy reports having seen nests at a height of eight to ten feet in the branches of thorn-trees (*Cratægus*) in southern Wisconsin. The nests are made of leaves, fine grass, etc.

The food of this species is vegetable matter—seeds, nuts, grasses, and herbage. In captivity, according to Merriam, it will eat flesh and catch flies and eat them. Other observers have failed to induce them to eat any flesh. They may store up food for winter, as nuts, grains, seed, etc., have been found in their storehouses, sometimes in considerable quantities. They do not hibernate, but are active all winter, and their tracks are often seen in the snow.

The following table shows the result of an examination of fifty-five females.

| Date | Accessions number | Condition of female. |
|---|---|---|
| Jan. 1..... | 37921 | Parturition shortly before. |
| Jan. 1..... | 37922 | Four embryos—full grown. |
| Jan. 1..... | 37923 | Two embryos—full grown. |
| Jan. 2..... | 37931 | Uterus shrunken and empty. |
| Jan. 2..... | 37932 | Uterus small, empty. |
| Jan. 2..... | 37933 | Three small embryos. |
| Jan. 2..... | 37934 | Uterus small, empty. |
| Jan. 2..... | 37936 | Uterus small, empty. |
| Jan. 2..... | 37939 | Uterus small, empty. |
| Jan. 2..... | 37941 | Recent parturition. |
| Jan. 3..... | 37954 | Uterus small, empty. |
| Jan. 3..... | 37955 | Uterus small, empty. |
| Feb. 14..... | 38342 | Uterus medium-sized, empty. |
| Apr. 4..... | 37983 | Three embryos—size of peas. |
| Apr. 18..... | 37989 | Uterus swollen, empty. |
| Apr. 18...... | 37991 | Four embryos—nearly grown. |
| May 11..... | 13829 | Four embryos—three-fourths grown. |

| Date | Accessions number | Condition of female |
|---|---|---|
| May 26..... | 37927 | Uterus small, empty. |
| June 17..... | 38373 | Recent parturition. |
| June 26..... | 38387 | Uterus empty. |
| July 1..... | 38395 | Uterus small, empty. |
| July 1..... | 38399 | Five very small embryos. |
| July 1..... | 38402 | Four embryos—full grown. |
| July 1..... | 38404 | Uterus small, empty. |
| July 3..... | 37794 | Four embryos—nearly grown. |
| July 10..... | 38412 | Parturition recent. |
| July 10..... | 38415 | Uterus small, empty. |
| July 10..... | 38417 | Uterus small, empty. |
| July 16..... | 38419 | Uterus small, empty. |
| July 28..... | 38440 | Uterus medium-sized, empty. |
| July 28..... | 38442 | Uterus medium-sized, empty. |
| July 29..... | 38449 | Uterus medium-sized, empty. |
| Aug. 18..... | 38478 | Embryos present but minute. |
| Sept. 12..... | 37839 | Nursing. |
| Sept. 13..... | 37840 | Small embryos, 2 mm. long. |
| Sept. 19..... | 37841 | Uterus minute, empty. |
| Sept. 19..... | 37842 | Five-embryos—nearly grown. |
| Sept. 19..... | 37843 | Uterus large but empty. |
| Sept. 20..... | 37847 | Uterus shrunken and empty. |
| Sept. 20..... | 37848 | Five embryos—nearly grown. |
| Sept. 20..... | 37848a | Recent parturition. |
| Oct. 1..... | 37877 | Uterus small, empty. |
| Oct. 2..... | 37881 | Uterus small, empty. |
| Oct. 2..... | 37883 | Uterus small, empty. |
| Oct. 16..... | 37890 | Uterus small, empty. |
| Oct. 17..... | 37899 | Recent parturition. |
| Oct. 17..... | 38201 | Five embryos—full grown. |
| Oct. 17..... | 38204 | Uterus small, empty. |
| Oct. 17..... | 38206 | Uterus small, empty. |
| Oct. 31..... | 38250 | Uterus medium-sized, empty. |
| Oct. 31..... | 38626 | Uterus shrunken, empty. |
| Nov. 1..... | 38257 | Parturition recent. |
| Nov. 13..... | 38279 | Uterus medium-sized, empty. |
| Dec. 31..... | 37913 | Uterus empty. |
| Dec. 31..... | 37915 | Uterus small, empty. |

An examination of the table shows that young are born at all times of the year from January to October inclusive. It would seem likely that the same individual might produce three litters a year. The number in a litter is rather small, varying from two to five, with an average of a little less than four.

Apparently the sexes are separated during a good part of the year. At any rate the specimens caught during a night in a limited area almost invariably show a great preponderance of one or the other sex.

Although these mice are supposed to be nocturnal in their habits, Fisher has shown that a number of them are taken by hawks.* Many are caught by owls, which, with weasels, skunks, and snakes, are probably their chief enemies in this vicinity.

Although these mice are undoubtedly the most numerous mammals in the county, from an economic standpoint they are probably of little importance. They enter grain and corn fields and nest under the shocks, but the grain or corn eaten at first is usually waste. If, however, corn is allowed to remain in the shock till late in the winter, considerable damage may be done to it by these mice. They are said to enter barns and granaries in winter. A few such instances in this state have come to my notice.

## WHITE-FOOTED PRAIRIE-MOUSE.

*Peromyscus maniculatus bairdii* (Hoy and Kennicott).

*Mus bairdii* Hoy and Kennicott, Kennicott, Agr. Rep. Comm. Patents, 1856, pp. 92–95, Pl. XI.

*Peromyscus michiganensis* of authors, not of Audubon and Bachman.

According to the recent arrangement of the genus by Osgood the *maniculatus* group, containing some 30 forms, is scattered over various parts of North America from the arctic plains on the north to the central part of Mexico on the south. The form *bairdii*, of which the type locality is Bloomington, McLean county, Illinois, is said to have the following range: "Prairie region of the upper Mississippi Valley in southern Wisconsin, Minnesota, Illinois, Indiana, eastern Ohio, Iowa, Missouri, Oklahoma, and the eastern or humid parts of

* "The Hawks and Owls of the United States," Bull. No. 3, Div. Ornith. and Mamm., U. S. Dept. Agr.

Kansas, Nebraska, South Dakota, and North Dakota; north to southern Manitoba."*

The following table gives the measurements of specimens from various localities.

| Number of specimens measured and places of capture. | Average length | | | | | | Ratio of length of tail to length of head and body |
|---|---|---|---|---|---|---|---|
| | Total | | Head and body | | Tail | | |
| | in. | mm. | in. | mm. | in. | mm. | |
| 71 from Champaign county... | 5.28 | 134 | 3.27 | 83 | 2.01 | 51 | .63 |
| 30 from Illinois outside of Champaign county........ | 5.24 | 133 | 3.19 | 81 | 2.05 | 52 | .64 |
| 47 (Coues') chiefly from Wisconsin and Illinois..... | 4.96 | 126 | 2.95 | 75 | 2.01 | 51 | .68 |

It should be noticed that the specimens of Coues were apparently measured as alcoholics. If that be the case, the fact will explain the shorter body and the consequent greater ratio of tail to body-length in his measurements.

The maximum total length I have found, is 149 mm. The average length of the hind foot for specimens in the county is 17.6, and the outside height of the ear averages 13.6 mm. The ratio of the length of the tail to the length of the body, which gives one of the most constant distinctions between this species and *P. leucopus*, generally lies between .58 and .65. In a few cases it lies below these limits, but in only five instances in one hundred and fifteen specimens did it rise to .70.

In all immature and many mature specimens the general color over the upper parts is dark gray with a shade of umber, giving a tint much resembling wood-brown of Ridgway's nomenclature. This is darker towards the back, becoming nearly black along the middle line from the nape to the rump. The cheeks and back of the ears are smoky gray, as is also the upper surface of the tail and the

* Osgood, W. H., in "Revision of the Mice of the American Genus Peromyscus." N. Am. Fauna, No. 28, p. 79.

area around its base. The belly, chin, throat, inner side of legs, under side of tail, and usually the toes, are white. The white of the feet is modified to a greater or less degree by black hairs, producing a grayish color. The ears are sparingly covered with short dusky hairs. About one half the whiskers are white.

In older specimens the color of the upper part is warmed with a burnt-umber shade; the cheeks, back of the ears, and a line along the side and around the base of the tail become fawn-color; and the whole back is warmed to a greater or less degree, often quite equaling the average *P. leucopus* in liveliness of color.

Close examination will show that the base of the hairs is in general dark plumbeous, the only exception being the hairs of the toes, chin, and under side of tail, which may be white to the base. The tips of the hairs over all the under parts are white. Over the upper parts there are long hairs tipped with black or dusky, and shorter hairs which may acquire more or less of fawn or umber at their tips. The colored tips of those nearest the middle line are commonly paler and shorter than those of the side, while the black hairs are more abundant along the middle of the back. The upper surface of the tail may remain dusky or acquire a slightly umber tone. The feet usually become more nearly pure white with age.

Within the county this species is practically limited to the till plains and the highly cultivated areas of the moraines. It is emphatically an inhabitant of the open fields, differing from the preceding species far more noticeably in its habits than in its structure. It is the most characteristic mammal, and the most abundant one, of the great fields of the till plains. During late winter, spring, and early summer it is nearly the only mammal resident in the center of the great corn and grain fields of the county. Other species frequent the edges of the fields or enter them in fall when the grain is ripe, but this species is apparently present in the very center of the largest fields, even during those months when, owing to vigorous cultivation, the conditions seem most unfavorable.

The following table illustrates the local distribution of the species according to habitat.

| | Champaign county | Elsewhere in state | Total |
|---|---|---|---|
| Taken in Till Plain | 47 | 5 | 52 |
| Moraine | 10 | 2 | 12 |
| Bluff | 1 | 0 | 1 |
| Flood-plain | 1 | 0 | 1 |
| Woodland | 0 | 0 | 0 |
| Pasture | 0 | 4 | 4 |
| Total | 59 | 11 | 70 |

So far as my own experience goes I have never taken a specimen in woodland, or under stump, brush-heap, or other cover than such a temporary one as a shock of corn or grain, and even here one is quite as successful if traps are set in the rows between the shocks as if set under them. Others report their nests under boards, fence rails, logs, etc., but the only nests that I have found that were undoubtedly of this species, were in burrows in open fields. The burrows are small, about 2 cm. (.8 in.) in diameter. They descend perpendicularly about 10 cm. (4 in.), then run horizontally, for perhaps 50 cm., to the nest. This is composed of nibbled straw or grass. They store up seeds and grain in these burrows. They do not hibernate, but are certainly more or less active all winter.

An examination of a limited number of stomachs indicates that when seeds, grain, fruit, and other available vegetable food is present, their diet is varied but strictly vegetarian. Specimens taken in the center of large, well-cultivated corn fields, however, where there was little vegetation except the young growing corn, had resorted to an insect diet. While they undoubtedly do eat grain, still, even when that is present, it constitutes only a part—and apparently the smaller part—of their food. In illustration of this, I may mention a nest found in the stubble of an oat field which contained a store of grass seed but no oats. Again, the stomach of a specimen taken in late fall in a corn field where there was abundance of fallen corn, showed on examination that 25 per cent. of the contents was undigested seeds of a ground-cherry (*Physalis lanceolata*);

hence over 50 per cent. of the bulk of the food was probably the fruit of that plant. Many similar illustrations could be given.

Kennicott says that white-footed prairie-mice injure young fruit-trees by gnawing at the roots. It is possible that when young trees are set out on the prairie this might happen, though even then I should be inclined to suspect that a meadow-mouse was the culprit till it was proven otherwise. In any case this species does not seek nurseries, small-fruit patches, etc. Even in a cemetery in which they were very abundant in open places, I have never taken them in the neighborhood of shrubbery.

An examination of 24 females made to determine time of breeding, number in litter, etc., gave the following result.

| Date | Accessions number | Condition of female. |
|---|---|---|
| Feb. 16..... | 38349 | Uterus small, empty. |
| Feb. 19..... | 37858 | With 2 young, 81 mm. long. |
| Feb. 23..... | 37110 | Pregnant; 4 small embryos. |
| Mar. 26..... | 37977 | Nursing. |
| June 11..... | 38359 | Five embryos. |
| Aug. 30..... | 38603 | Uterus small, empty. |
| Oct. 3..... | 39606 | Uterus empty but swollen. |
| Oct. 3..... | 39607 | Six embryos, 2 mm. long. |
| Oct. 26..... | 38228 | Uterus small, empty. |
| Oct. 26..... | 38230 | Uterus small, empty. |
| Oct. 30..... | 38236 | Nine embryos. |
| Oct. 30..... | 38239 | Uterus empty, mammæ large. |
| Oct. 30..... | 38240 | Seven embryos, half grown. |
| Oct. 31..... | 38246 | Seven embryos, a fourth grown. |
| Oct. 31..... | 38249 | Six embryos, nearly grown. |
| Nov. 5..... | 39635 | Five embryos, nearly grown. |
| Nov. 5..... | 39638 | Uterus empty but swollen. |
| Nov. 10..... | 38269 | Uterus small, empty. |
| Nov. 10..... | 38270 | Four embryos, very small. |
| Nov. 14..... | 38286 | Uterus empty. |
| Nov. 20..... | 39652 | Uterus empty. |
| Nov. 20..... | 39654 | Uterus empty. |
| Nov. 30..... | 38295 | Uterus small, empty. |
| Nov. 30..... | 38296 | Uterus small, empty. |

This would seem to indicate that there are three broods a year at about equal intervals of four months; viz., in the latter part of February, in June, and in October.

The number in a litter varies from four to nine. This agrees in general with such records as have been made by other observers. The young adhere to the teats with considerable tenacity, and have often been seen clinging to the dam when the nests were disturbed. The smallest specimen found pregnant was 129 mm. in total length. The average length of all my specimens being 134 mm., I am inclined to believe that they breed first when about one year old.

The enemies of this species, as of the white-footed wood-mouse, must be the nocturnal *Carnivora* found in the open fields, viz., skunks, weasels, and owls. Very few have been found in the stomachs of hawks.

Economically their importance seems to be small, for good or ill. I have no record of their injuring growing crops in this locality, and the grain taken, while perhaps considerable in total amount, is chiefly waste. The species does not habitually feed on grain in shocks, and so far as any available record goes it never enters barns or granaries.

Owing to the clearing of woodland and the drainage of waste tracts, the area of its habitat within the county has undoubtedly greatly increased since the settlement of the country, and, considering its advantageous adaptation to the present state of cultivation, it seems quite certain that there are more individuals within our limits now than when the country was unsettled, and that its numbers are not diminishing at present.

### SOUTHERN GOLDEN MOUSE.

*Peromyscus nuttalli aureolus* (Audubon and Bachman).

*Mus* (*Calomys*) *aureolus* Aud. and Bachm., Proc. Acad. Nat. Sci. Phil., I., 1841, pp. 98–99.

A few specimens of a golden mouse identified by Osgood as probably of this form, were taken near Olive Branch, Alexander county, in the extreme southern part of the state. They were quite abundant in the low woods of oak bordering the cypress swamps. Kennicott reported it from Murphysboro, in Jackson county, and from Salem, in Marion county. The latter locality is probably near the northern limit of its range.

The golden mouse is easily recognized by its color, which is a rich tawny-ochraceous above and creamy white below. Nothing seems to be known of the habits of this most beautiful animal. I found it living with the white-footed wood-mouse, both being taken under the same log; but while the wood-mouse was taken also on the wooded hills in the vicinity, the golden mouse seemed to be limited to the low woods bordering the swamps. Kennicott says that the golden mouse takes to a tree readily when pursued, and that in the vicinity of Salem it often built nests in the branches of low trees. Its nests "were like birds' nests, but covered at top, with a small opening on the side."

### FLORIDA WOOD-RAT.

*Neotoma floridana* (Ord).

*Mus floridana* Ord, Bull. Soc. Philom. Paris, 1818, p. 181.

There is a single specimen of this species in our collection, taken by A. Hempel at the Quiver Cut-off, at Havana, Ill., July 17, 1895. It was found in a log on shore.

This wood-rat closely resembles the common brown rat in appearance, but the color on the back and sides is rufous, and the feet are pure white. In the southern part of the United States it is said to be common along streams. According to Knox,* "They build nests by piling up sticks and pieces of bark, to the height of two or three feet, often about the base of a tree or stump. In the middle of these piles they have a nest of dried grass and leaves."

Kennicott published a plate of the wood-rat † but gave no information in regard to it. I find no record of its occurrence within the state.

*"Kansas Mammalia," Trans. Kan. Acad. Sci., Vol. IV., p. 21.

†Trans. Ill. State Agr. Soc., Vol. II., Pl. XIV.

## PENNSYLVANIA MEADOW-MOUSE.

### *Microtus pennsylvanicus* (Ord).

*Mus pennsylvanica* Ord, Guthrie's Geogr., 2d Am. ed., II., 1815, p. 292.
*Arvicola riparius* Kennicott, Trans. Ill. State Agr. Soc., II., (1856–57), p. 677.

This species was called the long-haired meadow-mouse by Kennicott. It has not yet been found in Champaign county. There are several specimens in the collections of this Laboratory that were taken near Normal, in McLean county, and I took two specimens in a tamarack swamp in McHenry county.

Like the prairie meadow-mouse, this species rarely leaves the shelter of dense low-growing vegetation. It is found in wet meadows, in waste corners of cultivated fields, and in woodlands and wooded swamps. Its nests are said not to be in burrows but under stumps, logs, etc. In winter it is sometimes found on the surface of the ground, with no cover but the deep snow. In such situations the heat of the animal forms a large dome beneath the snow, and from this many runways extend in all directions. When the snow thaws, these nests are deserted. The underground burrows of this mouse are shallow and simple, often not extending beyond the log or other cover under which they are dug.

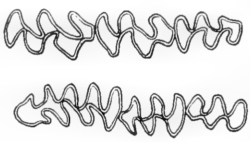

Fig. 1. Molar enamel pattern of Pennsylvania meadow-mouse. (Bailey.)

The species is said to breed from March to November inclusive. There are probably three litters of five to eight in a year.

The economic relations of this species are similar to those of the prairie meadow-mouse, but the species is so rare, in this part of the state at least, that it has practically no economic importance.

## PRAIRIE MEADOW-MOUSE; PRAIRIE-VOLE.

### *Microtus austerus* (Le Conte).

*Arvicola austerus* Le Conte, Proc. Acad. Nat. Sci. Phil., VI., 1853, pp. 405–406.

The range of this species, according to Bailey*, is the central part of the Mississippi Valley, from southern Wisconsin to southern Missouri and Fort Reno, Oklahoma, and west into eastern Nebraska and Kansas.

* "Revision of American Voles of the Genus Microtus," N. Am. Fauna, No. 17, p. 73.

The average measurements for 29 specimens, most of them from this county, are as follows: Total length, 5.47 in. (139 mm.); tail, 1.22 in. (31 mm.); hind foot, .75 in. (19 mm.). There is considerable variation in the length of the tail, our specimens ranging in this respect from 1.02 in. (26 mm.) to 1.58 in. (40 mm.).

The upper parts are dark gray, with a peppery appearance due to the mixture of black and pale fulvous tips of long hairs, the black-tipped ones predominating. The sides are paler, the belly is washed with pale cinnamon, and the tail is bicolor. The base of the hairs is everywhere plumbeous.

Kennicott regards this species as the most abundant native mammal on the prairie of northern Illinois. In this county I think that it is outnumbered on both till plains and moraines by the white-footed prairie-mouse, and in many localities, during the autumn, by the common house-mouse. It is, however, very difficult to estimate the number of these mice present in any area. They seem to possess the same migratory instinct as their near relatives, the lemmings, frequently moving from place to place. At any rate, in common with other observers, I have often taken them in comparative abundance in a locality where the year before or the year after not a specimen could be obtained by prolonged trapping. There is also a temporary shifting to grain and corn fields in fall and late summer, and a return to the shelter of fences, edges of woods, etc., in winter. Kennicott describes the species as being most decidedly an inhabitant of the prairie, and declares that he has never found it in the woods; while observers in other localities report it as having a most decided preference for the edge of woodlands or open groves. So far as my own observation goes, it is the ground-cover which determines the habitat of these meadow-mice. They are not found in closely grazed pastures nor in well-cultivated fields of corn, vegetables, etc., but they may occur wherever there is a close growth of grass or other low vegetation. Where this condition prevails I have taken them in groves and in fairly dense and extensive woods, though their favorite situations are the waste places along fences, in the corners of fields, and in permanent pastures. They are also abundant at times in alfalfa and clover

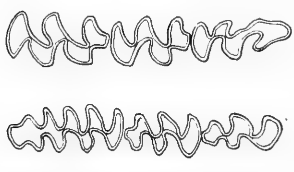

Fig. 2. Molar enamel pattern of prairie meadow-mouse. (Bailey.)

fields. When grain or corn is shocked they soon take up their residence under the shocks.

While not more than a single family is found in a nest, they are usually so associated that they may be abundant in one limited locality though entirely wanting in a similar one near by.

They are found on the margins of the flood-plains down to the border of the sedge zone, but they do not enter that zone as a usual thing. Although always more numerous on high ground, they are also found in considerable abundance along the borders of the flood-plains, and are often driven out of their burrows there by the spring floods. At such times I have found them clinging to stumps and other objects that rose above the water. On my approach they would take to the water, swimming easily, and diving and escaping if pursued.

The habits of this species were studied and well described by Kennicott in northern Illinois forty-five years ago, and we can do little more than confirm his observations. The presence of these mice is always indicated by their runways through the grass. They seldom move by leaping, but creep close to the ground, keeping under cover whenever possible. Similar runways are sometimes made by the white-footed mice and shrews, but theirs are much the longer and more extensive, as those species do not object to running out in the open. The runways are about one and a half to two inches in diameter, and it is said that the mice make them by biting off and beating down the grass. The runways communicate with burrows four to eight inches below the surface, which may form an intricate network. The nests may be built above ground or below. They are globular in shape, about six inches in diameter, and are entered from below. They are constructed of soft grass. Those which are built below the surface are for winter use, though under haycocks and similar shelter the mice are found in winter occupying nests above ground. Often a nest so located, with its associated runways, is in close connection with a subterranean nest, which is also connected with a mesh of subterranean runways lying below those on the surface.

These meadow-mice do not hibernate, though they store up considerable supplies of food. This consists of grass and various roots. Kennicott found in their burrows roots of *Liatris*, *Helianthus*, *Silphium*, wild onion, and grasses.

In many localities this species undoubtedly does the most damage of any of our smaller mammals. An extensive investigation by the U. S. Department of Agriculture showed that immense damage was done at times, in various localities, by field-mice of this and closely related species. They destroy shocked grain and corn; they eat roots when stored in heaps, or even when growing; and they destroy clover, alfalfa, and grass in meadows. But perhaps the most common and grievous complaint made against them is that they girdle young trees, especially in orchards and nurseries. They have been charged in this county with all these classes of injury. However, conditions here are not such as to render the farmer liable to extensive damage by these pests. Corn is not often shocked, grain is usually threshed very shortly after cutting, and as meadows are seldom kept in grass for many consecutive years the mice do not get well entrenched in them. Again, but little attention is paid to fruit-raising, and so there is no great damage to fruit-trees. Perhaps, in this county, truck-farmers and growers of small fruit suffer more loss from this mouse than any other class. In an adjoining county I have seen fields that had been kept in clover for two or three years abundantly infested by these mice, considerable damage to the crop resulting. They are hardly numerous enough with us at present to be denominated a pest, but their record in other localities shows how easily, under favorable circumstances, their numbers may so increase as to render them a serious menace to the farmer.

So far as I know, no claim can be urged in their favor except the rather dubious one, put forth by Rhoads, that they furnish food for hawks, owls, and carnivorous mammals. It is true that their favorite resorts are usually the waste places neglected by the farmer, that the green food they eat would not be utilized otherwise, and that a large part of the grain they destroy is waste; but, nevertheless, to the grower of garden-truck and fruits their presence is always a menace, and any signs of their unusual abundance should be regarded as a call for prompt action.

The field-mice demand a close cover of soft, low-growing herbage for their nests and runways. Where there is a heavy snowfall which lies undisturbed for weeks, they venture out under it into fields bare of vegetation, but such conditions are rare in this county.

The most favorable place for trapping meadow-mice is a broad strip of unkept sod along a fence between two corn or grain fields. Waste spots in permanent pastures next to cultivated fields are also favorite localities; but where weeds and grass are kept down by pasturage or tillage, meadow-mice are rare or lacking. Thorough cultivation and frequent rotation of crops will prevent these animals from becoming a pest.

As is the case with all the small mammals, climatic conditions have a great influence, directly and indirectly, on the abundance of these mice. It has been observed that, in general, open winters followed by wet summers are most favorable for their increase. If an abundance of grain or other food is present also, marked increase in their numbers is sure to be noticed. Such conditions increase the number of litters and the number in a litter, and probably shorten the time required for attaining maturity.

The enemies of meadow-mice include practically all the carnivorous mammals, the birds of prey, and the majority of our snakes. Among the mammals of this county, weasels and skunks are the most important agents in the repression of these mice and other small rodents. Weasels especially, being fairly abundant, destroy large numbers of mice, and thus probably repay in the fields what they cost in the poultry-yard. Hawks and owls are also great destroyers of field-mice of all kinds. This species, not being strictly nocturnal, more often falls a prey to the hawks than do some of the other species. To the nurseryman or gardener a nest of hawks or owls in the vicinity is worth many dollars. Other birds also, as herons, crows, cuckoos, shrikes, and bitterns, destroy these mice.

If only a limited area is to be cleared of meadow-mice they may be trapped. The small, single spring traps used for house-mice are the most satisfactory. They may be baited with oatmeal and placed near the runs. Some are successful with an unbaited trap put across the runway. Over a larger area they may be cleared out by poisoning. The poisoned bait is prepared as described in the note following this paper. It should be so placed that neither birds nor domestic animals may get it. It is best to place it in the vicinity of their nests under boards slightly raised, or in pieces of small-sized tiling, old cans, or the like. One must bear in mind, however, that in using poison one always runs some risk of doing damage.

In the case of this species it is probably always easier, by thorough tillage, to prevent its becoming a pest than to destroy it after it has become abundant.

### MOLE MEADOW-MOUSE; MOLE-LIKE VOLE.

*Microtus pinetorum scalopsoides* (Audubon and Bachman).

*Arvicola scalopsoides* Aud. and Bachm., Proc. Acad. Nat. Sci. Phil., I., 1841, p. 97.

I have never identified an individual of this species among our specimens, and I doubt if it is found in this county. Kennicott reports it as common in the northern part of the state. He says that it is readily distinguished from the other meadow-mice "by its smaller size, glossy fur, large muzzle, small eyes, and very short tail." In technical works the distinction is based on the number of mammæ and the form of the teeth. The mammæ in this species are four in number, while there are eight in the other species of *Microtus* found in the state. In this species (Fig. 3), the enamel pattern of the third molar forms two triangles, while in the other species it forms three (Fig. 1 and 2).

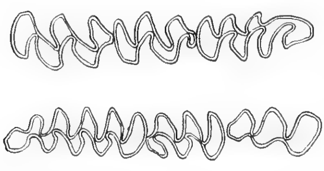

Fig. 3. Molar enamel pattern of mole meadow-mouse. (Bailey.)

This meadow-mouse inhabits woods rather than open fields, and was called the wood meadow-mouse by Kennicott. Otherwise, so far as known, its habits are in general similar to those of the other meadow-mice.

### MUSKRAT; MUSQUASH.

*Fiber zibethicus* (Linnæus).

*Castor zibethicus* Linn., Syst. Nat., I., 1766, p. 79.

The muskrat, under several subspecies, is found generally throughout North America from northern Mexico to Hudson Bay. The range of the typical form which is found in Illinois is given by Elliot as "Labrador to the Gulf States, excepting possibly the Dismal Swamp, Virginia, and from the Atlantic Coast to the Rocky Mountains north of the Gulf States and Arizona, and south of Keewatin, Canada."

Throughout its range, wherever there is quiet water with abundant aquatic or riparian vegetation, the muskrat is sure to be found unless driven away by persistent persecution. In early days the sloughs that covered a large part of the prairie were the resort of thousands of these animals. Here they found plenty of food and comparative safety from their enemies. As these swampy areas have been drained, the range of the muskrats has become restricted to drainage ditches and the natural watercourses. Although this change in the environment has necessitated a change in habits, the muskrats, with a strange persistence, still remain, and wherever in the till plains or in the sags of the moraines there is still open water enough to wet their feet, traces of their presence may be found. They will not disappear until the drainage is entirely under ground.

In this vicinity the burrows of the muskrat along the banks of streams and ditches open near the level of moderately low water, and extend back some yards into the bank. There are usually openings to the surface also, back some distance from the water. Some of these openings are the work of the muskrats, but many of them are due to the breaking-through of men or animals into the burrows.

When the country was new the muskrat houses were a prominent feature in the landscape, and they may still be seen occasionally. Observers differ greatly in regard to the conditions under which muskrats may or may not build houses. Evidently their habits in this respect differ in different localities. In the lakes and marshes of Wisconsin, Minnesota, and Canada they build houses in two to four feet of water wherever conditions permit. In this vicinity the houses are found in much shallower water, and in the southern part of its range the muskrat does not build houses at all. This has apparently become a matter of individual variation in this county, for one finds only a small proportion of these animals using houses where, so far as one can see, conditions are equally favorable for all to build them if they wished. These houses serve a double purpose, furnishing both shelter and supplies of food—the interior part consisting of such food plants as are available in the locality. The houses are built solid at first, the interior excavation being made later. While the bottom and interior part are composed of closely packed food-plants, above and on the exterior dirt is mixed with them, and, occasionally, drift materials. Where the water is deep, the beginning of the house is often made in the form of a raft of edible roots. This raft is added to till its weight sinks it to the bottom. After the solid stack is completed a small cavity is hollowed out in the middle, a little above the water-line, and a runway—sometimes more than one—leading from it is dug down to and under the water. A number of individuals occupy the same house.

The great bulk of the food of the muskrat is vegetable matter—chiefly roots of aquatic and riparian plants. When corn, grain, vegetables, or apples are convenient, the muskrat helps itself to them, and may go a few rods from the water to visit a field or storehouse containing them. At times muskrats feed extensively on fresh-water mussels*. Observations indicate that the more delicate species are taken out on the bank and opened at once with the teeth, while the heavier and stouter species are not opened till they are weakened by lying there. That muskrats eat dead or living fish at times is vouched for by a number of good observers†.

From three or four to at least as many as nine young are produced in a litter. The northern trappers believe that the female produces two broods the first year and three for several years after. The young are hairless and quite helpless when born.

Considerable damage is done by muskrats in fields of corn and grain, though it is seldom serious in any particular locality. Wherever a corn field touches the banks of a stream or ditch, muskrat trails running from the water into the edge of the crop are common. Growing corn is usually cleared off systematically over a small area and carried to the water and eaten. Comparatively little is wasted, stalk and all being eaten. Grain fields in proximity to water are also entered and the grain is cut down, the heads being either eaten on the spot or carried to the edge of the field or into the water. Grain is also carried off after it is harvested and in the shock. Muskrats also damage root-crops when these are grown near their resorts.

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* I am indebted to Mr. James Zetek, of the State Laboratory, for the identification of the following species which had been opened by muskrats on a sand-bar of the Sangamon River, near White Heath. The pile of empty shells included 7 shells of *Symphynota*, 41 of *Quadrula undulata*, 4 of *Q. pustulosa* and 1 of *Q. coccinea*, 7 of *Lampsilis luteolus* and 1 of *L. ventricosus*, 3 of *Tritogonia tuberculata*, 3 of *Alasmodonta complanata*, and 1 of *Anodonta grandis*.

†Bull. U. S. Fish Comm., Vol. IV., pp. 297–298.

Great injury to dams, or other walls of earth used for confining water, may result from the burrowing of muskrats, since their excavations are the beginnings of breaks that may become extensive and entail enormous loss. In this part of the state the loss is chiefly restricted to the banks and immediate vicinity of water-courses. The burrows run back for a considerable distance, and, being near the surface of the ground, cause the banks to cave in and obstruct the stream. Horses and cattle also break through into the burrows, making holes that are both unsightly and dangerous.

In spite of the fact that muskrats are both prolific and locally abundant, they can hardly be regarded as a serious pest. They are easily trapped, and it is seldom that they occasion more loss in a locality than their hides are worth. Traps may be set in the entrance of their burrows or where their runways enter the water; or they may be set near their feeding grounds and baited with a bit of parsnip, carrot, or sweet apple. The bait should be supported over the trap on a stick. If possible the trap should be so placed that the animal may get into deep water when captured; otherwise it is very apt to amputate the limb that is caught and escape.

The skins of muskrats form an important item of the fur trade. From three to four million skins are used yearly, and three fourths of these are from the United States. Their price has varied considerably. At one time they sold for as much as fifty cents apiece, and then were worth more than mink skins.

### COOPER'S LEMMING; COOPER'S LEMMING-VOLE.

*Synaptomys cooperi* Baird.

(N. Am. Mamm., 1857, p. 558.)

The range of this species is from eastern Massachusetts to Minnesota, and south to North Carolina, Tennessee, Indiana, and Iowa.

In color and form this lemming resembles a meadow-mouse, but it is easily recognized at once by the grooves along the front of the broad incisors. It is really a form connecting the meadow-mice, or voles, and the true lemmings; the name "lemming-vole" is therefore the most appropriate one, though too awkward for common use.

Everywhere within its range this species seems to be the rarest of the small mammals—or, at least, the one most seldom trapped. The only two specimens in our collection were found together in the vicinity of Urbana. They were both dead, and the head of one had been eaten off. Persistent trapping in the same vicinity failed to give us any others. Collectors throughout all its range agree in regard to its remarkable scarcity. The only place where it seems to have been even moderately abundant is in the vicinity of Brookville, Indiana, and about the only observations we have on its habits were made by Quick and Butler* at that place. They found it most numerous on hillsides in high, dry blue-grass pastures, where stones are irregularly scattered over the surface. Our specimens were found on a low bluff overlooking a creek, in pasture-land where there were stumps and scattered trees. However, the dead animals may have been merely brought there. Other collectors have taken them from swamps—wet or dried-up—and from spruce woods, *Sphagnum* bogs, etc.

Quick and Butler say that these animals breed from February to December, and that the nests, made of soft dry grass, are always under cover, often in hollow logs or stumps.

The food of Cooper's lemming is entirely vegetable so far as known, consisting of stems and roots of grass and other plants. The form of its incisors would seem to prevent it from eating nuts or hard-shelled seeds. It stores up various kinds of roots for winter.

Its numbers are said to vary greatly at Brookville from year to year.

### POCKET-GOPHER.

*Geomys bursarius* (Shaw).

*Mus bursarius* Shaw, Trans. Linn. Soc., V., 1800, pp. 227–228, Pl. 8.

This animal derives its name from the pockets in its cheeks. They are lined with fur and open on the outside. Its total length is about 10.85 in. (275 mm.). The tail is 3.34 in. (85 mm.) long. The color is nearly chestnut above and below, but paler on the belly. The feet are whitish.

The pocket-gopher is found in the prairie region of Illinois, in the southern half of Wisconsin, in Minnesota very nearly up to the Canadian border, in the eastern part of the Dakotas and Nebraska, and in northeastern Kansas and Missouri. It is strictly an inhabitant of the prairie throughout this range.

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* Am. Naturalist, Vol. XIX., pp. 113, 114, 115, 116, 118.

We have no specimens from this county, nor have I actual proof of its being found here. Several times the presence of its burrows in the county has been reported, but each time investigation has shown that the burrows observed were the work of moles. I have taken it in Mason county, and it is reported to be common in the western part of the state.

This animal leads a life so largely subterranean and nocturnal that it is seldom seen. We have taken specimens within a few rods of the house of a farmer who had never seen the animal before though he had lived in that locality over twenty-five years. Its presence is plainly indicated, however, by small mounds of earth thrown up from its burrows. These mounds usually vary in diameter from a few inches to two feet, and are eight or ten inches high. On the prairies in the West, or wherever they are undisturbed for a long time, they may be of much larger dimensions. No opening is evident in these mounds, the earth of which they are composed being pushed out ahead of the animal, and the last load left to block the entrance. The extensive burrows are from one to two feet below the surface, and their general location is indicated by the dirt-piles, and never by ridges on the surface as are those of moles. They also differ from mole-runs in being deeper and larger, and in the fact that the dirt from them is brought to the surface—not simply pushed aside, as is so often done by the mole. In digging its burrow, this gopher pulls the earth back under it with its fore feet, then kicks it still farther back with its hind feet, and finally, when a considerable quantity has accumulated, it turns in its burrow, brings its fore feet together with the palms vertical and at right angles to the body, and with its hind legs pushes itself and the dirt out of the burrow. Merriam says that it can run as fast backward as forward, and that in carrying food it usually does so, reminding one of the motion of a shuttle.

Very rarely solitary specimens are seen above ground, evidently prospecting for a change of locality. They apparently live in solitude except for a short time while mating. The eyes are small and the animals appear intolerant of bright light, carefully closing all openings into their burrows. They are extremely silent creatures, the only noise they ordinarily make being a hiss that appears to be merely a forcible inspiration and expiration of air. Under rare circumstances they utter a feeble squeak. It is doubtful if the sense of hearing plays any very important part in their life. Merriam suggests that the naked tail may serve as an organ of touch to guide the animal when running backward through its burrow.

The food of this gopher consists largely of such vegetable matter as can be obtained under ground, that is, roots, tubers, and rhizomes of various plants. They use practically everything of this kind that they meet with. Even trees so large as six inches in diameter have the roots cut off and eaten by them. They also come out of their burrows at night under cover of vegetation and eat and carry away seeds and vegetative parts of plants. These are stored in their pouches and carried to underground storehouses connected with their runways.

The pocket-gopher is not known to hibernate. Where the ground does not freeze severely it may continue burrowing all winter, storing the dirt from its excavations under the snow.

Pocket-gophers are not fertile when compared with most other mammals, and their abundance in certain localities is due rather to their ability to escape their enemies than to their fertility. Available data indicate that while two to six may be produced in a litter the average number is about three, and that there is but one litter a year. The young are born in spring, about the end of April. By the middle of June they may be half grown and starting their own burrows.

As these gophers appear so rarely above ground, they suffer comparatively little from natural enemies. A few are killed by hawks, still more are caught by owls, and probably all the larger *Carnivora* sometimes surprise and capture them; but once safe in their burrows, even the fox and the badger can not easily get them. Probably their chief enemies in this state are the weasel and some species of snakes. The former is able to follow the gopher into its burrow and kill it, and it is known that some of the larger snakes do the same.

In this part of the state, pocket-gophers are too rare to be of any importance economically, but in other sections of the country they are often a serious pest. In nurseries and forest plantations they do great damage by gnawing off the roots of small trees. When they attack a tree their habit is to gnaw off all the roots at the base, thus leaving the tree without any means of support. Trees of considerable size are destroyed in this way. These gophers do great damage to root-crops also, potatoes being sometimes so badly injured that those remaining are not worth harvesting. Grain, either from the standing crop or from the shock, is likewise taken down into their burrows.

The piles of earth thrown up from their runways disfigure the fields, cover the crops more or less, and are in the way of the harvester or mowing-machine.

It has been urged in favor of the pocket-gopher that it benefits the soil by working it over; by burying vegetable matter, which decays and increases fertility; and by bringing the deeper layers of the soil under the influence of the atmosphere. However this may be, when the gopher prosecutes this system of cultivation in the midst of a meadow or an alfalfa field his efforts are not appreciated, and he must go.

There are but few pests more easily gotten rid of. The simplest and safest way under ordinary circumstances is to trap them. The most satisfactory trap is the ordinary No. 0 steel one. To set it, dig down to the burrow, choosing a place one or two feet from a recently cast-up dirt pile. Be careful to remove all dirt dropped into the runway. Excavate a slight hollow and set the trap so that it will be nearly on a level with the bottom of the run, and sprinkle it over with fine dirt, nearly covering it. Cover the opening loosely with a bit of board or sod, not excluding quite all the light.

This gopher may be poisoned by introducing poisoned grain (see final note) into the burrow through a small hole. The use of poison always involves some risk, but it can seldom be more safely used than for the pocket-gopher.

### JUMPING MOUSE; HUDSON BAY JUMPING MOUSE.

*Zapus hudsonius* (Zimmermann).

*Dipus hudsonius* Zimm., Geogr. Gesch. d. Menschen u. vierfüss Thiere, II., 1780, p. 35.

This is a northern species, ranging from the southern shores of Hudson Bay south to New Jersey and, in the mountains, to North Carolina, west to Iowa and Missouri, and northwest to Alaska.

It seems to be nowhere abundant. Kennicott reported it from the northern part of the state, but we have no Illinois specimens. It may be recognized by its long hind legs and its long jumps when escaping pursuit. Its color somewhat resembles that of the white-footed wood-mouse, but is rather more ochraceous over the upper parts. Its habits, also, so far as known, resemble the habits of that species. It was found hibernating, however, by Hoy.

It is extremely desirable that specimens of the species found in the state should be reported. It is apparently much rarer here than formerly, and may be on the verge of extinction.

### SWAMP-RABBIT; SWAMP-HARE.

*Sylvilagus aquaticus* Bachman.

(Journ. Acad. Nat. Sci. Phil., 1837, p. 319.)

This species is found in the cypress swamps in the southern part of the state as far north as Cape Girardeau, Mo. Its range south extends to the Gulf.

It is much larger than the common rabbit. A specimen taken December 28 near Olive Branch, Alexander county, gave the following measurements: Length, 19.8 in. (503 mm.); tail, 2.17 in. (55 mm.); hind foot, 4.33 in. (110 mm.); ear, 3.7 in. (94 mm.).

The general color scheme is similar to that of the cottontail. The cheeks, sides of head, and the nape are gray; the sides of the body are gray with a faint wash of ochraceous; and the top of the head and the back are pale ochraceous much mottled with a rich black. There is a well-defined spot of rusty cinnamon on the shoulder, and the upper part of the feet is tawny ochraceous. The under parts are pure white but for an ill-defined color of faint ocher under the throat.

This species keeps to the deep swamps in this state. It swims readily, and when pursued takes to the water, and may even dive to escape. It is said that even on dry land it rests on logs or stones rather than in forms. Evidently this is a habit that has grown out of its living in swamps.

Young are produced at least twice a year, and in litters of four to six.

### COMMON RABBIT; COTTONTAIL.

*Sylvilagus floridanus mearnsi* (Allen).

*Lepus sylvaticus mearnsi* Allen, Bull. Am. Mus. Nat. Hist. N. Y., 1894, p. 171.

E. W. Nelson, in his recent monograph of the Rabbits of North America (N. Am. Fauna, No. 29) refers the rabbits of this section to this form. The range as given by that author is as follows: "West of Alleghany Mountains from Lake Simcoe, Toronto, Canada, central New York, central Pennsylvania, western West Virginia, and eastern Kentucky, and eastern Tennessee, west through southern Michigan and Wisconsin to southeastern Minnesota, and south through Iowa to Trego county, Kansas, northern Missouri and Illinois, with all of Indiana and Ohio."

The following description is based on the examination of forty-seven specimens, all shot December 5, 1908, in the same locality. The records of all the specimens shot of which a complete record could be given are included. Probably a good proportion of the specimens were born that season.

The average measurements are given below.

| No. of specimens measured | Average length | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Total | | Tail | | Head and body | | Hind foot | | Ear | |
| | in. | mm. | in. | mm. | in. | mm. | in. | mm. | in. | mm. |
| 25 females | 16.72 | 424.2 | 1.66 | 42.2 | 15.06 | 382. | 3.86 | 97.9 | 2.7 | 68.6 |
| 22 males | 16.52 | 419.9 | 1.66 | 42.2 | 14.86 | 377.6 | 3.89 | 98.8 | 2.74 | 69.6 |
| Average for the 47 | 16.60 | 422.2 | 1.66 | 42.2 | 14.94 | 380. | 3.86 | 98.1 | 2.72 | 69. |

The accompanying polygon of lengths of body and head shows better than the above the range in size.

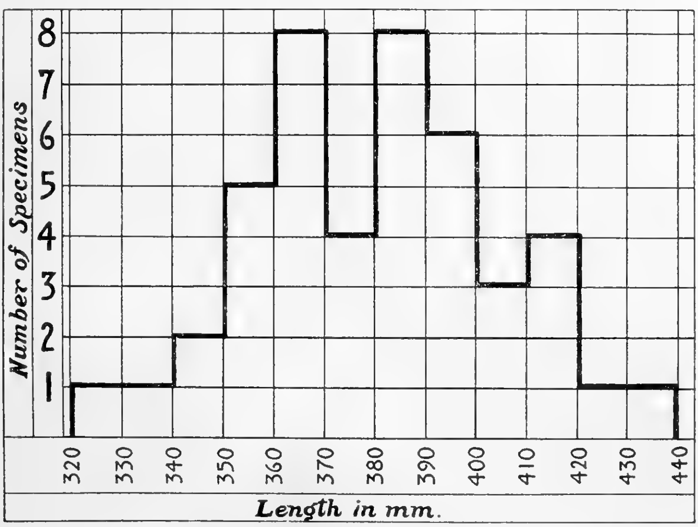



Fig. 4. Polygon of lengths of 44 individuals of the common rabbit.

The hair is everywhere plumbeous at base, and the following description applies only to the outer portion of the hairs.

On the chin, on the lower edge of the upper lip, on the belly and breast, and on the *most* of the inside of the thighs and on the under side of the tail the hair is white. On the upper parts in general, the finer, shorter hairs are tipped with a pale chestnut. The longer hairs usually have a band of black followed by one of cinnamon, and, finally, a black tip (often lacking), the general effect produced being a mottled black and cinnamon. This is characteristic of the top of the head, the side of the shoulders, and the back. On side of head, cheek, and over rump and upper part of outside of thigh the cinnamon band is lacking, being replaced by a soiled creamy white, and the general color is gray. The hairs on the nape, and backward over the shoulder are cinnamon-color, varying to vinous cinnamon. The outside of the front leg, a spot just in front of the groin, and the back part of the thigh are also cinnamon. From the spot in front of the groin an ill-defined band of pale vinaceous cinnamon extends along inside of the thigh to the heel. The front edge and tip of the ears outside are black, the rest being cinnamon-gray. The inside of the ear is white at the tip. The margin is also white except the lower outer portion, which is gray. Above the eye is a grayish spot. In some specimens the neck is encircled by a broad grayish cinnamon collar, which is quite clearly defined, especially below, by the white of the breast.

The chief variations from the description are as follows: (1) The collar just mentioned may be very obscure. (2) In about half of the specimens there is a trace of a white spot between the eyes, and this, when present, may be quite conspicuous, or it may be represented by half a dozen white hairs. (3) The inside of the thighs is sometimes flushed with buff; and (4) the rump and upper part of tail at the base may be more or less cinnamon.

Estimated by bulk or weight, rabbits undoubtedly represent more mammalian life than any other wild animal in the county, and they are found in every part of it—prairie or wooded bluff or flood-plain. They are now the chief reliance of our sportsmen in the fall, and many hundreds of them are killed within a few miles of Champaign and Urbana. Their persistence in spite of furious persecution is really remarkable. They are found within these city limits at all times of the year, but appear especially abundant in the early winter after the first falls of snow. On mornings following a snow storm in early winter the hunters are especially numerous in the country, and even in the vicinity of these cities one may hear an almost continuous fusillade. At such times the rabbits appear to come in through the "firing line," and take refuge in the cities. Fortunately they are not hunted to any great extent except during a few weeks in the year, and the larger carnivores and birds of prey which are their natural enemies are nearly extinct in the county.

While rabbits are perhaps more abundant in the vicinity of groves or the edges of woods, they are found wherever there is sufficient vegetation to conceal them. On the prairie, during the spring, before vegetation appears, they are hard pressed for shelter, but hedges, the waste ground along fences, ditches, and roads serve, with their unremitting vigilance, to tide them over till the new growth furnishes them abundant cover. Later, they are found in the corn fields, where they often remain all winter, making nests under some exceptionally large clod or under fallen stalks of corn. After a heavy snowfall they are easily taken in these places, being loth to leave them, and appearing stiff and stupid when driven out. They also winter in the woods, and probably the larger number of those in the vicinity of timber take to brush-heaps, thickets, etc., for shelter during the winter. Many, however, are true inhabitants of the prairie, remaining there the whole winter through.

In general the rabbit is decidedly non-resistant, but at times, the mother may defend her young by kicking with her hind feet, and a blow from a rabbit's foot, with its heavy nails, is not to be despised. But fighting is always a last resort with rabbits, and flight is their usual recourse for safety, and all the peculiar adaptations of the animal seem made to that end. Their senses of hearing and of sight are remarkably acute, and the flexibility of the ears and the position of the eyes make it possible to use both through a wide angle. It would seem that the sense of smell is also acute, though not so much relied on. Though the necessities of their existence in a well-cultivated district like this, demand that rabbits be constantly alert, they are essentially crepuscular or nocturnal, feeding chiefly from sunset to sunrise.

Under natural conditions, their food, so far as known, is entirely vegetable. In confinement the female may eat her young, and the male is given to destroying them. It is probable, however, that this occurs but rarely in nature. While grain and roots may be eagerly eaten by these animals when they can be had, ordinarily by far the larger part of the food is the vegetative part of plants, including leaves, stems, twigs, and bark. Of these a wide variety is used. Much of their food is furnished by plants not useful to man.

The rabbit is proverbially prolific, though not more so than many other rodents. There are usually four to six in a litter, and in this latitude probably at least three litters a year. Rabbits are polygamous. The young are born in shallow nests lined with grass, on which the mother lays hair from her own body. She occupies a separate nest near her young. They become mature at an early age, and may bear young—possibly two litters—before they are a year old.

Rabbits destroy small quantities of small grain, corn, and vegetables, but this loss within the county can not be very considerable. Possibly their chief injury here is done by barking and gnawing young trees. In other localities at least, this loss becomes a serious matter to the nurseryman and fruit-grower, though it is not apt to occur except where considerable snowfalls cover other sources of food. This has not often happened with us in recent years, and as fruit-growing is a very subordinate business in this county I doubt if the damage to fruit-trees by rabbits amounts to very much.

As they furnish about the only game throughout most of the county, hunters are well able and more than willing to keep them in check *gratis*. If they were to be entirely protected for a few years over any considerable territory there is no doubt that they would become a pest.

### AMERICAN RABBIT; VARYING HARE; WHITE RABBIT.

*Lepus americanus* Erxleben.

(Syst. Regn. Anim., I., 1777, p. 330.)

According to Kennicott,* several individuals of this species were shot on the present site of Chicago in the winter of 1824. It is probably extinct in the state at present.

The species is much larger than the common cottontail, and its fur turns white in winter.

It is a northern species, its range extending nearly to the Arctic Ocean.

* Rep. Comm. Patents, 1857, p. 84.

## FLESH-EATING ANIMALS.

## *CARNIVORA.*

### PANTHER; PUMA.

*Felis concolor* Linnæus.

(Mantissa, 1771, p. 522.)

Kennicott reports a single individual in Cook county. Individuals must often have followed up the larger rivers in the state in early times. Among the earliest settlers of this county I find a general impression that panthers were sometimes seen here, but I have been unable to obtain any definite data.

### CANADA LYNX.

*Felis canadensis* (Kerr).

*Lynx canadensis* Kerr, Anim. Kingd., 1792, pp. 32, 157.

This species is listed by Kennicott as found in Cook county, and two species of lynx, or wildcat, are recorded as being in the state by various early writers. Owing to the common confusion of the two species it is perhaps impossible to tell now to what extent, if at all, this species was present within the state. It is not likely that it was ever seen by a white man within this county.

### WILDCAT.

*Felis ruffa* Güldenstaedt.

(Nov. Comm. Acad. Imp. Sci. St. Petersburg, XX., 1776, p. 484.)

Wildcats were formerly found throughout the state wherever there was extensive heavy timber, and they are still not uncommon in the heavily wooded portions in the south. I obtained the skull of a specimen at Olive Branch, Alexander county, in 1908. A number of them had been killed in that vicinity. Merriam says that in the Adirondacks they nest in hollow trees, making a soft bed of moss. From two to four young are produced in a litter. In thinly settled sections the wildcat often destroys the farmer's lambs, small pigs, and poultry. Their regular food in a wild state consists of rabbits, squirrels, and other small mammals, together with such birds as they can get. The early settlers of the county declare that wildcats were found in the county between 1835 and 1840, but I can get no proof of their being found later.

### TIMBER-WOLF.

*Canis occidentalis* (Richardson).

*Canis lupus occidentalis* Richard., Fauna Bor. Amer., Mamm., I., 1829, p. 60.

The timber-wolf ranged originally over all the timbered portions of the United States and the adjoining portions of Mexico and Canada. Whether all the forms found in this territory should be classified as belonging to one or more species has not been well settled. They were formerly abundant along the wooded bluffs and the forest areas everywhere throughout Illinois, and are still found in the state occasionally in various localities.

The species varies so greatly in both size and color that no exact description of it can be given. Judging from the scanty material available, perhaps the average specimens met with in this state might be described as follows:

Length, 4 feet (1220 mm.); tail, 15 inches (380 mm.).

Young pups with soft woolly hair, buff to ochraceous in color, lighter below. Ears tipped with tawny ochraceous bordered with black.

General color of adult gray, with more or less ochraceous. Color lighter below, the feet sometimes becoming nearly white.

In the wilderness wolves live chiefly on rabbits and deer. The number of deer killed by them is enormous. In more civilized sections of the country they take up with whatever animals they can catch and kill. Their liking for sheep is proverbial, and a bounty on wolf scalps is still offered in most parts of the state. During the years 1883 to 1905 inclusive, bounties were paid on 159 wolves killed in Champaign county. Wolves have been reported within the county since that date, and it is not at all unlikely that a few still exist in the heavy timber along the Sangamon River and the Vermilion.

They den in such shelter as is furnished by caves, upturned trees, etc. There are six to ten pups in a litter. Judging from the list of bounties paid in this county, the number in a litter here is from four to nine.

### PRAIRIE-WOLF; COYOTE.

*Canis latrans* Say.

(Long's Exped. Rocky Mts., I., 1823, p. 168.)

Prairie-wolves were formerly abundant throughout the prairie and plains region of the United States and Canada to the Saskatchewan. A wolf reported to be of this species was killed in Winnebago county, Illinois, during the winter of 1908–09, but we have not been able to verify the identification. The early settlers declare that prairie-wolves were still common in this county about 1850, and that they were seen ten years later.

### RED FOX.

*Vulpes fulva* (Desmarest).

*Canis fulvus* Desm., Mamm., I., 1820, p. 203.

The red fox is found from the Canadian boundary south to Georgia and west to the great plains.

This fox is too well known to need description. It is one of the few medium-sized mammals that by their adaptability and cunning manage to exist in a well-settled country. Twenty or thirty years ago it was very abundant in this county, and is now by no means rare. It is an inhabitant of the bluffs, though it makes excursions for some distances into the adjoining country.

Foxes prey on every living thing that they can catch and overcome. They do not disdain carrion, and when hard pressed by hunger have been known to turn vegetarians and eat apples, grapes, and strawberries.

They produce four to nine pups in a litter, rather early in spring.

In a wild and rough country foxes make their dens at times in caves, under ledges of rock, and even in hollow stumps and logs. In this vicinity they are probably always in burrows.

When captured young, the red fox is easily tamed and makes an interesting pet. It is exceedingly playful, and comes to enjoy human society, but unless much and wisely handled is apt to become treacherous as it gets older. A young fox in captivity at Mahomet, in this county, enjoys being taken to the fields and allowed to hunt grasshoppers, and is quite clever in catching them.

Except by destroying game, foxes do very little damage in the county at present. Poultry-yards are so well guarded and easily accessible food so abundant that foxes are not tempted to make a raid on the farmers' hens. On the other hand, they destroy mice and moles, and thus make some compensation for the game they kill.

### GRAY FOX.

*Urocyon cinereoargenteus* (Müller).

*Canis cinereoargenteus* Müll., Natur. Suppl., 1776, p. 29.

The gray foxes, including several subspecies, are found in timbered regions in all parts of the United States and Mexico. The type species occurs from Georgia north to New England and west through the timbered portions of the Mississippi Valley.

The gray fox is about the size of the red fox. The general color of the upper parts is a mixture of gray and black. The outside and base of the ears, the side of the neck, the edges of the belly, and more or less of the outer side of the limbs are ochraceous to cinnamon-brown. There is a band of black across the muzzle. The lower half of the head, chin, and sides of muzzle are white. The under parts are ferruginous.

The gray fox was originally fairly abundant in this county, but is now quite rare. Its general scarcity as compared with the red fox is probably due to a difference in habit. It is not a burrowing animal, and is more dependent than the red fox on heavy timber and an unsettled country for dens and shelter. It is therefore far more intolerant of civilization than the red fox, and is replaced by that species as the country becomes thickly settled.

### BLACK BEAR.

*Ursus americanus* Pallas.

(Spicileg. Zool., Fasc. XIV., 1780, p. 5.)

The black bear is found in the eastern part of North America wherever forests are found, except in Labrador, Florida, and Louisiana. Closely related species continue the range to the Pacific and south to Texas.

I have not been able to find any one among the early settlers who could vouch for a bear's being seen in the county. They were common in the river bottoms in the southern part of the state, and it is more than likely that they sometimes followed up the rivers to the borders of this county. They are probably extinct now in Illinois.

### RACCOON; COON.

*Procyon lotor* (Linnæus).

*Ursus lotor* Linn., Syst. Nat., I., 1758, p. 48.

The common raccoon, under various forms, is found throughout the United States and Mexico, and north into southern Canada. It occurs throughout Illinois, and is not rare in this county.

Raccoons haunt wooded bluffs and the timbered flood-plains, and are seldom found far from them. They may make raids into corn fields and chicken-houses at some distance during the night, but they spend the daytime in some big hollow tree in the woods, and when pursued always seek shelter in a tree. They have been known in severe winter weather to live around haystacks and outhouses, but this is very unusual.

The raccoon is an omnivorous carnivore, as the rat is an omnivorous rodent, and its food, like the rat's, varies with the time and place, being largely a matter of what it can get. It is fond of berries and other fruits, and will eat most garden vegetables, though it prefers those that have a sweetish flavor. Its liking for young corn is well known. It eats crayfish, and has been accused of catching minnows and trout. It is exceedingly fond of eggs, as well as of birds and poultry, if it can get them. It also eats, with apparent relish, grubs and various insects which it picks out of holes and crevices, and it is said to kill and eat small mammals at times. The specific name *lotor*—meaning washer—was applied to the coon because of its well-known habit of washing its food before eating it. The instinct is a curious one, and I know of no satisfactory explanation of it. The animal is very fond of paddling in the water, and a pair of tame raccoons kept by Godman would indulge in this sport even in the coldest weather, when the ice had to be broken in order to let them get to the water.

In this latitude the raccoon breeds in March or April, but the breeding season is a month later in the Northwest Territories of Canada. The usual litter contains from four to seven young.

In the extreme northern part of its range the raccoon hibernates during the most severe weather, but in this latitude, though less active and disposed to take long naps during the cold weather, it is doubtful if it ever falls into a profound winter sleep. In captivity it shows a remarkable indifference to cold or inclement weather.

As a pet, none of our mammals is a greater favorite. Though it is always mischievous and destructive if opportunity occurs, its interesting and affectionate ways keep it in favor.

Raccoons do a certain unknown amount of good by destroying insects injurious to forest-trees. They also destroy crayfish and small mammals, and possibly in that way benefit man at times. The mischief they do in corn fields, in chicken roosts, and to useful birds is well known. Whether the balance is in favor of or against the coon depends on circumstances; but, in any case, in a portion of the state so poorly provided with objects of sport as this the raccoon merits more sympathy and protection than it receives.

### BADGER.

*Taxidea taxus* (Schreber).

*Ursus taxus* Schreb., Säugth., III., 1778, p. 520.

Kennicott, in his list of the mammals of Cook county, published in 1854, says the badger was formerly common in that county, and was still so farther south. It is reported that a specimen was killed a few miles north of Urbana in 1908. The dead animal was seen by reliable persons, but I have not been able to verify the identification by seeing its skin. The badger undoubtedly occurs in the northern part of the state, though I have no reliable record of one's being found recently.

### SKUNK.

*Mephitis mesomelas avia* (Bangs).

*Mephitis avia* Bangs, Proc. Biol. Soc. Wash., XII., 1898, p. 32.

The skunks of this locality are referred to the above subspecies, the type of which came from San Jose, Mason county, Illinois. There is considerable variation in size, color, etc. The description given by the author of the subspecies is as follows: "Black all over except white frontal stripe, nuchal patch, and two lateral stripes extending back from nuchal patch. Tail very short and bushy, black externally, most of the hairs white at base. Total length 607–675 mm. [24–26.5 in.]. Tail vertebræ, 177–190 mm. [7–7.5 in.]. Hind foot, 65 mm. [2.56 in.]."

Skunks are found in all situations in the county, being most common about the pastures and bluffs, but are nowhere very abundant. As they are the least shy of all our larger mammals and make their presence known in a variety of ways, they are not apt to be overlooked in any locality.

Skunks walk on the soles of the feet, with the body somewhat arched and the tail more or less elevated. When disturbed they erect the long hair on the back and tail, displaying to the fullest the contrasting black and white as a warning. The tail is waved vigorously, giving rise to the impression that the offensive liquid which the animal secretes is flung on its enemies by that means. As a matter of fact, it is ejected in slender jets from glands near the anus. The secretion is a straw-colored fluid lighter than water, containing a number of organic substances called mercaptans. Inhaled in large quantities, the vapor acts as an anæsthetic, producing unconsciousness, heavy breathing, and coldness of extremities. It would undoubtedly prove fatal if inhaled too long.

This secretion seems to be an extreme development of what is common to other animals, especially minks and weasels, which are the skunk's nearest relatives. What in them is probably a secondary sexual character, by which the sexes detect or allure each other, has become in the skunk, by further development, its most potent defense, on which it depends almost entirely for its safety. It is clumsy in its movements, can neither climb nor swim well, and yet no other mammal in the state is so independent and shows such indifference to its enemies.

The dens of skunks are chiefly burrows, but it is said that nests are sometimes made by these animals in stumps, hollow trees, etc. They occasionally take refuge under barns or even beneath houses. They are said to be gregarious, a large number—not all of the same family—being found in one den. They are chiefly nocturnal in their habits, though their indifference to danger allows them to remain abroad till daylight.

Skunks probably make use of all kinds of animal food that they can get. They are preeminently insect eaters, destroying enormous numbers of the largest insects, both adult and larval. They catch frogs, salamanders, mice, and other small mammals, and they eat the eggs and nestlings of such birds as nest low, sometimes, no doubt, getting the birds themselves. Unfortunately for its reputation the skunk does not hesitate to take the farmer's eggs and poultry when they come in its way, and when once it discovers where they may be found it shows considerable persistence and cunning in getting them. Eggs are eaten on the spot. Fowls are killed by a bite on the neck, and are usually carried away.

The young, six to ten in number, are produced in spring.

The skunk does not hibernate except in very severe weather—probably not at all in this locality.

Under present conditions in the county, there is probably no mammal more unjustly persecuted than the skunk. Its offensive odor is only used in self-defense, and it is easy to guard against its raids on poultry-yards. A less defensible damage is that caused by its destruction of the eggs and nestlings of ground-nesting birds; but whatever damage may be done in this way is undoubtedly more than compensated by its destruction of enormous quantities of grubs, grasshoppers, large beetles, etc., and by the large numbers of mice and voles which it destroys. Merriam says on this subject: "I do not hesitate to assert that a single skunk nets the farmer more in dollars and cents each year than he loses from their depredations during his entire lifetime."

The skin of the skunk forms an important article of the fur trade, its value depending largely on the color, as well as on its size and condition. In general, the more nearly black a skin is, the more valuable it is.

The flesh of the skunk is said to be white and tender and of delicious flavor. It is needless to say that the scent-glands should be carefully removed before cooking.

Those who have had the temerity to try it, assert that the skunk, if taken young, makes an inoffensive and delightful pet, becoming gentle and playful, and showing no inclination to use its battery.

Skunks are easily trapped, their self-confidence making them exceedingly careless.

### AMERICAN MARTEN; HUDSON BAY SABLE.

*Mustela americana* Turton.

*Mustela americanus* Turton, Linn. Syst. Nat., I., 1806, p. 60.
*Mustela martes*, Auct.

Recorded by Kennicott from Cook county, Illinois. Long extinct within the state. No record of its occurrence in this county.

### FISHER.

*Mustela canadensis* Schreber.

(Säugth., III., Text, p. 492, 1777, Pl. CXXIV., 1776.)

Kennicott says that "the fisher used frequently to be seen in the heavy timber along Lake Michigan." It is now extinct throughout the state so far as known. There is no positive proof that it was ever taken in this county.

### MINK.

*Putorius vison* (Schreber).

*Mustela vison* Schreb., Säugth., III., 1777, p. 463.

The mink is found, under suitable conditions, throughout the United States and British America to Hudson Bay and northern Alaska.

The length of the common mink is from 15 to 18 inches (381 mm. –450 mm.), and the length of the tail is 6 to 8 inches (152 mm.–203 mm.).

Its color varies from a dull yellowish-brown—near russet of Ridgway—to a deep chocolate or seal-brown, but slightly, if at all, paler below. The tail is darker—blackish. The chin, and usually a patch on the breast and several spots between the fore legs are white. The tip of the tail also is sometimes white.

Though never abundant in this state, the mink is found along all our watercourses. Next to the otter it is the most expert in aquatic life of any of our mammals. Nevertheless, it is sometimes found quite remote from any water, and readily makes its way over long distances when streams or ponds are frozen or dried up. A goodly number are taken in this county each winter, many of them being caught in the mouths of tile-drains along drainage ditches in the open country. Wherever there is a farmhouse near a stream there is pretty sure to be complaints of loss of poultry by minks. In some cases the trespasser has been caught in the act, but probably a weasel or a rat is sometimes the true culprit.

The mink swims swiftly, with the whole body, except the nose, submerged, and dives so skillfully that it can follow and catch trout and other active fish. While not an expert climber, it can ascend surfaces that furnish a nail-hold, but its active life on land is spent chiefly near the ground, creeping through brush and weeds, stalking its prey. Observers are not agreed as to whether it digs its own burrow or not. Certainly it sometimes takes possession of a muskrat's hole, ejecting the rightful owner. Minks' nests are also found in hollow logs, under old stumps, and in similar localities. They are made of soft grass or leaves, and lined with feathers and hair.

If circumstances are favorable for the mink in its preferred resorts along streams or other bodies of water, its food will be largely fish, bugs, crayfish, or mussels, with an occasional muskrat; but it is apt to forage also, more or less, in the adjoining territory, catching mice, rats, and rabbits, and stealing birds' eggs. Its reputation for robbing poultry-yards is well known, though the majority of observers agree that, unlike the weasel, the mink seldom kills more than two or three fowls at a time.

The mink produces one litter a year, in April or May. Gestation lasts 6 weeks, and the young are 6 to 10 in number. When born they are hairless, "about the size and shape of a little finger," but in a short time they are covered with a soft, thick, glossy fur. The young follow the mother till fall. The females are said to develop in ten months, while the males require 18 months to reach maturity.

Whether the mink is, on the whole, a benefit or injury to man depends on circumstances. Where mice, voles, rats, and crayfish are abundant, its good offices may predominate; but where these are lacking, and game-fish, game-birds, or poultry are within its reach, the account would surely stand the other way. In either case, so long as its pelt is so valuable there is little danger of the mink's becoming excessively numerous.

Mink fur is short, but thick and very durable, and the skin, though thin, is exceedingly tough. The price of the fur depends on its popularity, and consequently varies greatly from year to year.

Emmons, writing in 1840*, says: "The fur is of little value on account of its shortness, though it is quite fine." Later its beauty and durability began to be appreciated, and the price of mink skins rapidly rose, till, in 1865, skins of prime quality were quoted at $15 each. Since then the price has declined; but to-day the pelt of the mink, in proportion to its size, is more valuable than that of any other aquatic animal except the sea-otter and the best seal.

The mink has often been tamed, and is said to make a gentle and interesting pet, the only drawback being the exceedingly offensive odor which it produces at times.

Minks are often taken in this county in traps set in the opening of tile drains or old muskrat burrows. Traps are sometimes baited for them with bits of meat, small animals, or fish.

### WEASEL.

*Putorius noveboracensis* Emmons.

(Rep. Quadr. Mass., 1840, p. 45.)

*Putorius erminea* Coues. Fur-Bearing Animals, pp. 109–136 (in part).

This species occurs from Illinois east to the Atlantic, and from North Carolina and Tennessee north into Canada, while closely related species range as far north as the Arctic Ocean. All of these species were formerly included, with the ermine of Europe, under the name *Putorius erminea*.

Male and female weasels differ considerably in size, the average length of the male being 16.5 in. (407 mm.); tail vertebræ, 5.5 in. (140 mm.); and hind foot, 1.85 in. (47 mm.). The corresponding measurements for the female are 12.8 in. (324 mm.), 4.25 in. (108 mm.), and 1.36 in. (34.5 mm.).

In summer, the upper parts, including the feet, are a rich dark chocolate-brown, often near seal-brown. The under parts, as well as the upper lip, are white more or less washed with sulphur-yellow. In winter, in the southern part of its range, the whole animal becomes entirely white except the terminal third of the tail, which is jet-black. In the South the winter pelage is similar to that of summer, but a trifle paler. No white specimens are in our collection, but they have been reported within the county by reliable observers. In the northern part of the state they are common.

* A Report of the Quadrupeds of Massachusetts, p. 44.

The body is slender and cylindrical. The neck is remarkably long, and nearly as large in diameter as the body. The head is small and triangular in shape, the nose being pointed, and the cheeks are swollen with the enormous jaw muscles.

The weasel is probably found under all physiographic conditions represented in the county. My own records indicate its greatest abundance along the border of smaller watercourses in the till plains and the sags of the moraines. This indication of greater abundance, however, may be in part due to the fact that weasels are more conspicuous in such localities. Unlike the mink, they are not aquatic, and are not known to enter water for food. They climb readily, and leap from branch to branch like a squirrel.

All observers of the weasel have been struck with its fearless inquisitiveness and indomitable ferocity. Audubon says that it seems to possess an intuitive propensity to destroy every animal and bird within its reach, even some which are ten times its own size. It is, however, preeminently a mouse-catcher, and house-mice, field-mice, and voles form the bulk of its food in this locality. To these should be added, however, gophers, rabbits, chipmunks, birds' eggs, birds, and poultry—the latter an occasional indulgence. It is a question whether in this county weasels or rats should have the dubious honor of destroying the greater number of young chickens, but as to the destruction of half-grown or full-grown fowls undoubtedly the weasel destroys as many as are destroyed by all other pests together.

The weasel has but one litter a year. In this latitude the young are produced in April or May, the number in a litter varying considerably, from two to twelve having been reported.

The nests are found under such shelter as logs or stumps, and in hollow trees or in burrows. Some observers declare that they use the burrows of animals that they have dislodged, while others imply that they make burrows themselves. Possibly both statements may be true.

It can not be denied that the weasel kills many animals that man would prefer to kill himself. Besides its raids on the poultry roosts, it kills many rabbits, quail, and prairie-chickens. In the northern part of its range a single weasel has been known to kill as many as eleven rabbits during one night's raid. These were all dragged a short distance and buried in the snow. They had all been killed by a single bite between the eyes and the ears. Whole coveys of quail are often killed by weasels, but the marks of their teeth being very small, may be easily overlooked, and the quail be supposed to have frozen to death. On the other hand, it should be remembered that these raids on useful animals are comparatively rare, while every night in the year the weasel's unceasing slaughter of mice, rats, and other vermin goes on. It is probably a fact—hard as it may be to convince the farmer of it if his chicken-coop has been visited by weasels—that in the long run he receives more good than harm from them.

If their burrows are found it is not difficult to so set a trap at the entrance that they will be caught. Notwithstanding the common opinion to the contrary, weasels are neither very shy nor very cunning. I have repeatedly had them crop up within twenty feet and watch me from the sheltering undergrowth or a brush-heap.

### OTTER.

*Lutra canadensis* (Schreber).

*Mustela lutra canadensis* Schreb., Säugth., 1776, Pl. CXXVI., B; text, 1778.

The common otter was originally found in favorable localities throughout the United States, and in British America nearly to the Arctic Ocean. It is still sparingly scattered over this wide range.

I have not been able to find any proof of the otter's having been taken in this county, but at least an occasional one must have wandered along the larger rivers. Otters are still found in the swamps in the southern part of the state. During the winter of 1907–08 several were taken in the cypress swamps of Alexander county.

## INSECT-EATING ANIMALS.

*INSECTIVORA.*

### COOPER'S SHREW; LONG-TAILED SHREW.

*Sorex personatus* I. Geoffroy-Saint-Hilaire.

(Mém. du Mus. Hist. Nat. Paris, XV., 1827, pp. 122–125.)

*Sorex cooperi* Bachm., Journ. Acad. Nat. Sci. Phil., 1837, p. 388, Pl. XXIV., Fig. 7.

This little mammal is distributed over all the northern part of North America from the Atlantic to the Pacific, and south, in the mountains, to Tennessee and South Carolina. Kennicott reports it as far south in Illinois as Murphysboro, Jackson county. The only specimens in our collection are from Normal, in McLean county, and from a tamarack swamp in McHenry county.

This species is easily distinguished from our other shrews by its small size and long tail. The measurements for adult specimens are about as follows: Total length, 4 in. (100 mm.); tail, 1.5 in. (40 mm.); hind foot, .5 in. (12 mm.).

The color above is sepia, and the long hairs are tipped with clove-brown; below, it is ashy gray. The tail is dark above, whitish below.

We have taken the species only in swamps or low ground, but it has been taken in almost every possible habitat within its range. It has not been found in this county so far as I can ascertain, though it is probably present here in small numbers.

All that we know of its habits indicates that this species, like all the other shrews, is exceedingly energetic and voracious. Merriam says "In less than eight hours one of these tiny wild beasts had attacked, overcome, and ravenously consumed two of its own species, each as large and as heavy as itself." It does not hibernate, but is active all winter, even when the temperature is below zero.

The number in a litter, as reported, varies from two to ten. There are six mammæ, and probably they indicate about the average number of young. Embryos have been found in specimens from June to September at least. This would imply two or three litters a year.

So far as known this shrew is beneficial to man and worthy of protection. A closely related European species has been known to catch young trout, but the habit has never been reported for our species.

### BACHMAN'S SHREW.

*Sorex longirostris* Bachman.

(Journ. Acad. Nat. Sci. Phil., III., Part II., 1837, pp. 370–373, Pl. XXIII., Fig. 2.)

A single specimen taken November 14, 1907, in a tamarack swamp near Pistakee Bay, McHenry county, Illinois, is referred to this species by C. Hart Merriam. The skull was badly smashed by the trap. When Merriam's paper on the shrews was published, in 1895, the only known specimens of this species were a half dozen from Raleigh, North Carolina. In regard to our specimen sent to him Dr. Merriam writes as follows: "Unfortunately the skull is broken at the junction of the rostrum with the cranium proper, and as it has not been removed from the skin I am still in ignorance of the skull characters. The teeth, however, leave little doubt that the species is *Sorex longirostris*, of which we already have specimens from Indiana. Its occurrence in a tamarack swamp in extreme northern Illinois, however, is surprising."

The following are my own data on the specimen, taken from my note-book. Length, 76 mm. (3 in.). Tail, 31 mm. (1.2 in.). Hind foot, 11 mm. (.4 in.). Color (described after putting in alcohol but, I think, before any noticeable change had taken place): The back is sepia with clove-brown-tipped hairs mingled. These are more abundant toward the rump. The color is lighter below, varying through drab to drab-gray, and being still paler on the throat and chin. The tail is bicolor—clove-brown above, drab-gray below. The feet are drab-gray, but the palms and soles are darker.

I have ventured to call the species Bachman's shrew, rather than to translate the Latin specific name, *longirostris* (long-nosed), since in fact the muzzle of this species is broader and shorter than in our other species.

### SHORT-TAILED SHREW.

*Blarina brevicauda* (Say).

*Sorex brevicaudus* Say, Long's Exped. Rocky Mts., I., 1823, p. 164.

The typical form of the short-tailed shrew is found from western Nebraska and Manitoba to the Atlantic. On the south it intergrades with the subspecies *carolinensis*, which is found to the Gulf. I have referred all my specimens from the northern half of Illinois to the typical form, though it is possible that some of them are, rather, transitional forms. A few specimens taken in the southernmost county of the state, I have regarded as the above subspecies.

The average size for *brevicauda* given by Merriam* is about 125 mm. (4.92 in.).

The following table shows the measurements of 44 specimens from the northern half of the state.

* N. Am. Fauna, No. 10, p. 10.

| Accessions number | Sex | Length | | | | County |
|---|---|---|---|---|---|---|
| | | Total | | Tail | | |
| | | in. | mm. | in. | mm. | |
| 37805.... | Female... | 4.57 | 116 | .79 | 20 | Champaign |
| 37811.... | Female... | 4.06 | 103 | .94 | 24 | Champaign |
| 37816.... | Female... | 4.84 | 123 | .98 | 25 | Champaign |
| 37860.... | Male..... | 3.86 | 98 | .94 | 24 | Champaign |
| 37861.... | Male..... | 4.06 | 103 | .83 | 21 | Champaign |
| 37892.... | ?........ | 4.80 | 122 | .87 | 22 | Champaign |
| 37993.... | Female... | 4.80 | 122 | 1.02 | 26 | Champaign |
| 37994.... | Female... | 5.08 | 129 | 1.06 | 27 | Champaign |
| 38233.... | ?........ | 3.94 | 100 | .91 | 23 | Champaign |
| 38234.... | ?........ | 4.53 | 115 | .98 | 25 | Champaign |
| 38262.... | Male..... | 4.13 | 105 | .87 | 22 | Champaign |
| 38263.... | Male..... | 4.57 | 116 | .98 | 25 | Champaign |
| 38264.... | Female... | 4.49 | 114 | .79 | 20 | Champaign |
| 38277.... | Female... | 4.13 | 105 | .94 | 24 | Champaign |
| 38278.... | ?........ | 4.25 | 108 | .79 | 20 | McHenry |
| 38304.... | Female... | 4.45 | 113 | 1.02 | 26 | Champaign |
| 38324.... | Male..... | 4.49 | 114 | .71 | 18 | Warren |
| 38325.... | Female... | 4.61 | 117 | .94 | 24 | Warren |
| 38326.... | Female... | 4.53 | 115 | .75 | 19 | Warren |
| 38332.... | Male..... | 4.41 | 112 | .98 | 25 | Warren |
| 38334.... | Female... | 4.37 | 111 | 1.02 | 26 | Warren |
| 38335.... | Male..... | 4.65 | 118 | .71 | 18 | Warren |
| 38336.... | Female... | 3.97 | 101 | 1.02 | 26 | Warren |
| 38338.... | Male..... | 5.20 | 132 | .91 | 23 | Warren |
| 38340.... | Male..... | 4.88 | 124 | .75 | 19 | Warren |
| 38358.... | Female... | 4.25 | 108 | .87 | 22 | Champaign |
| 38364.... | Male..... | 4.49 | 114 | .83 | 21 | Champaign |
| 38372.... | Male..... | 4.92 | 125 | .94 | 24 | Champaign |
| 38390.... | Male..... | 5.08 | 129 | 1.02 | 26 | Champaign |
| 38405.... | Female... | 4.68 | 119 | .87 | 22 | Champaign |
| 38406.... | Female... | 4.65 | 118 | .83 | 21 | Champaign |
| 38428.... | Female... | 4.68 | 119 | .91 | 23 | Champaign |
| 38435.... | Female... | 4.45 | 113 | .79 | 20 | Champaign |
| 38436.... | Female... | 4.49 | 114 | .94 | 24 | Champaign |
| 38457.... | Female... | 4.53 | 115 | 1.10 | 28 | Champaign |
| 38463.... | Female... | 4.88 | 124 | .79 | 20 | McHenry |
| 38464.... | Female... | 4.68 | 119 | .79 | 20 | McHenry |
| 38469.... | Female... | 4.76 | 121 | 1.10 | 28 | McHenry |
| 38470.... | Male..... | 4.61 | 117 | 1.06 | 27 | McHenry |
| 38471.... | Female... | 4.13 | 105 | .83 | 21 | Champaign |
| 38472.... | Female... | 4.13 | 105 | .79 | 20 | Champaign |
| 38481.... | Female... | 4.57 | 116 | .94 | 24 | Champaign |
| 39602.... | Female... | 4.25 | 108 | .98 | 25 | Iroquois |
| 39629.... | Female... | 4.57 | 116 | .94 | 24 | Champaign |
| Average.. | .......... | 4.53 | 115 | .87 | 22 | |

Although shrews are among the most common of the small mammals on the farm they are often confused with mice or moles. They may be easily distinguished from all our mice by their long, pointed nose, by the absence of visible external ears, and by their short, glossy, velvet-like fur and short tail. They may be distinguished from moles by their much smaller size, and by their small front feet.

The color varies somewhat, but is usually sooty lead above and a lighter ashy lead below. There is sometimes a rusty flush to the color when seen in certain lights.

If there are any factors of environment that appeal especially to this shrew no observer has yet been able to determine what they are. All places seem alike acceptable to it, and any one who has trapped for small mammals long will be tempted to believe literally in the following statement of Rhoads: "Forest and plain, sand and clay, barren or fruitful field, backwoods and door-yard, heat and cold, wet and dry, day and night have common charm for this cosmopolite."* Our own specimens were taken in practically every form of habitat where any other small mammal was found—even in the center of large corn fields in summer, where the white-footed prairie-mouse was the only other resident. They are usually closely associated with field-mice or house-mice, being almost invariably taken in the same localities. Very rarely does it happen that any locality yields shrews alone.

Shrews inhabit burrows and runways very similar to those of the meadow-mice. To what extent these burrows actually are the work of the shrews themselves does not seem to be proven. That shrews do take possession of the burrows of meadow-mice seems certain, but it is generally supposed that they also make burrows of their own. Their nests are in burrows, and are made of leaves, grass, etc. Shull found one nest made entirely of the hair of meadow-mice.

The food of the shrews is extremely varied. They are known to feed largely on insects, larval and adult, worms, and snails. They also eat dead mammals, even of their own kind. In captivity at least, they attack mice much larger than themselves, and kill and eat them. Their ferocity is remarkable. I once put a small shrew into a tin bucket with a house-mouse of twice its own weight. The

* "The Mammals of Pennsylvania and New Jersey," p. 192.

shrew immediately attacked the mouse most furiously. The mouse simply fought in self-defense, but the shrew returned to the attack again and again. It would approach the mouse with its feet set far apart, its whole form showing a peculiar tense alertness and relish of the fray, noted by Kennicott. In less than ten minutes the shrew had chewed off one ear and bitten off the tail of the mouse, and, finally, by a lucky dash, had seized the mouse by the base of the skull, killed it instantly, and had eaten out the brains. They are supposed to eat but little vegetable food, but I have taken them in new traps baited with oatmeal alone, and their mouths were full of the oatmeal when caught. They have also been known to eat nuts.

There are four to six in a litter, and two or three broods a year. They may be born at any time of the year, though less frequently in winter.

Shrews are provided with large glands, in the vicinity of the shoulder, that give off an offensive odor, and presumably produce a taste displeasing to other animals. Cats and dogs seldom eat shrews, although they may kill them. To what extent these glands protect shrews against attack by wild mammals is hard to tell, but as shrews are often found dead and not eaten, it would seem likely that the larger wild carnivores kill them and leave them. Certainly these glands do not protect the shrews from hawks and owls, both of which feed on them extensively.

It is unfortunate, that the shrews should be so generally classed in the popular mind with mice. The only possible injury that shrews may do, is to destroy some insects that are beneficial to the farmer. This is merely a hypothetical injury, and is certainly more than compensated by the good they do. A. F. Shull,* who made an elaborate study of this species at Ann Arbor, Michigan, has estimated that a single shrew during one month might kill and use for food the equivalent of 20 meadow-mice, 30 house-mice, or 450 May-beetles. In captivity shrews killed and ate all mice confined with them, and there is no reason to believe that they are less bloodthirsty when free. Of course the proportion of mice, snails, and beetles or other insects in their food will vary according to circumstances, but in any case the insatiable ferocity of the shrews must work for man's benefit. Probably no other mammal, unless it be the skunk when on its good behavior, is so uniformly beneficial to the

* Am. Nat., Vol. XLI., pp. 495–522.

farmer. Shrews certainly merit better treatment than they usually receive at the farmers' hands. Fortunately they are shy animals, largely nocturnal in their habits, and so are seldom victims of man's stupidity.

### CAROLINA SHREW.

*Blarina brevicauda carolinensis* (Bachman).

*Sorex carolinensis* Bachm., Journ. Acad. Nat. Sci. Phil., VII., Part II., 1837, pp. 366–370.

I have referred a few specimens taken in Alexander county, the most southern county in the state, to this subspecies. The distinction between it and typical *brevicauda* is thus summed up by Merriam: "*Blarina carolinensis* is merely a small edition of *B. brevicauda*, lacking the more accentuated features of the latter in the way of massiveness and angularity of the skull and lower jaw. It differs also in the lateral unicuspidate teeth. They are more nearly vertical, and the fifth is generally hidden when viewed from the outside."

The measurements of my specimens are as follows.

| Accessions number | Sex | Length | | | | County |
|---|---|---|---|---|---|---|
| | | Total | | Tail | | |
| | | in. | mm. | in. | mm. | |
| 37916..... | Female... | 3.54 | 90 | .75 | 19 | Alexander |
| 37919.... | Female... | 3.46 | 88 | .87 | 22 | Alexander |
| 37920.... | Male..... | 3.62 | 92 | .75 | 19 | Alexander |
| 37926.... | Female... | 3.70 | 94 | ...... | ...... | Alexander |
| 37927.... | Male..... | 3.82 | 97 | .98 | 25 | Alexander |
| Average. | .......... | 3.62 | 92 | .83 | 21 | |

The habits of this subspecies agree in all respects with those of the short-tailed shrew so far as known, and economically it takes the place of that form in the southern part of the country.

## SMALLER SHREW.

### *Blarina parva* (Say).

*Sorex parvus* Say, Long's Exped. Rocky Mts., I., 1823, p. 163.

The geographic range of this species is from Texas and eastern Nebraska eastward to the Atlantic.

Measurements are as follows: Length, 2.95–3.15 in. (75–80 mm.); tail, .63–.71 in. (16–18 mm.); hind foot, .43 in. (11 mm.).

The color of the upper parts is sepia to dark hair-brown; the under parts are ash-gray. The tail is bicolor.

From data at hand one may conclude that the habitat of this shrew is as varied as that of the larger species. My specimens were taken in my garden in Urbana, in the barren sand area of Mason county, and in the till plains of Champaign county.

The species seems seldom to be abundant, and its habits have been little studied. Presumably they are much like those of the larger species.

## STAR-NOSED MOLE.

### *Condylura cristata* (Linnæus).

*Sorex cristatus* Linn., Syst. Nat., I., 1758, p. 53.

The range of the star-nosed mole is from Hudson Bay to Manitoba on the north, and to Minnesota, northern Illinois, and, in the mountains, to South Carolina.

So far as known it is nowhere common in Illinois, but is occasionally found in the northern part of the state. Professor Frank Smith, of the Department of Zoology of the University of Illinois, found a dead specimen in the vicinity of Urbana, and other reliable observers have reported it in the county. I have never been able to take it in Illinois myself, and there are no specimens in our collections. It is easily distinguished from the common mole by the fringed disk on the end of the nose.

The color is a dull sooty slate, without the glossy sheen of the common species.

The species is a northern one, and in the southern part of its range is found chiefly in cold damp localities. Excepting this preference for a moist habitat we know little difference between the habits of this species and those of the common mole.

It is too rare to be of importance economically in this state.

## COMMON MOLE; SHREW-MOLE.

### *Scalopus aquaticus machrinus* (Rafinesque).

*Talpa machrina* Raf., Atlantic Journ., I., 1832, p. 61.

The common mole, under various subspecific forms, is found over most of the eastern half of the United States. The range of the form called *machrinus* is given as Wisconsin and Minnesota to Tennessee and Missouri; and west to eastern Kansas, Nebraska, and southwestern South Dakota.

Teeth: incisors, $^3/_2$; canine, $^1/_0$; premolars, $^3/_3$; molars, $^3/_3$. The second and third incisors of the upper jaw are small and often missing. The molars and premolars have very irregular surfaces, the projections of the lower jaw fitting into corresponding hollows in the upper one, and *vice versa*. This construction of the teeth and the strictly up and down motion of the jaws are well adapted to the chopping up of insects or other animal food.

The average size of twenty-seven adult specimens from Champaign county is as follows: Total length, 7.13 in. (181 mm.); length of tail, 1.34 in. (34 mm.). Specimens from the western part of the state are somewhat larger. The fore limbs to the wrist, are concealed under the skin. The fore paws are enormously developed. The toes, five in number, are webbed their whole length. The length of the palm is .6 to .8 of an inch (15–20 mm.), but the width is greater, being from .8 of an inch to an inch (20–25 mm.). This great width is due to a flap of skin on the lower edge, the rigidity of which is maintained by an extra sickle-shaped bone. The palm is margined with stiff hairs. The nails are stout, flattened, semi-cylindrical, and translucent enough to shew the bifid tips of the last finger-bones within. The tail is squarish, especially at the base.

The nose is slender and pointed. The snout is prolonged beyond the lower jaw about .3 of an inch (8 mm.). It is flattened and deeply grooved below, and is truncate at the apex. The truncated surface looks upwards and contains the nostrils. At the tip is a hard, nail-like body. The thick fur hides the eye and the ear, but if the hair be cut off close both may be found. The eye appears as a protuberance, about the size of a pinhead, .8 to 1 inch (20–25 mm.) from the end of the snout. There is no true pinna, or external ear, but the external auditory opening is prolonged a short distance beyond the head by a cartilaginous tube.

The mammæ are six in number. The posterior pair are in the usual pelvic position, but the middle pair are so situated that the teats are near the knees. The front pair also are in an unusual position, being toward the back, and on the side, back of the fore leg. It is evident that if the mammæ were in the usual place beneath the body they could not be reached by the young, owing to the short legs of the dam and the projecting snout of the young moles.

The fur, except on the snout and extremities, is dense, fine, and silky, with but very little slope, so that it offers little resistance to rubbing in any direction. The general color is hair-brown, sometimes grayish, sometimes warmed to bister or sepia, but is always obscured by a shifting, sheeny luster. The base of the hairs is plumbeous. The chin, throat, upper surface of fore paws, and the wrists are much lighter in color, and often suffused with shades varying from ochraceous to ferruginous or, in spots, even to orange. The tail is whitish at base, nearly naked, and pinkish at the tip, as are also the tip of the snout and the toes.

The moles are almost unique among vertebrates in leading a truly subterranean life in burrows of their own construction, not only finding a refuge in them, like so many other animals, but also seeking their food by plowing their way through the ground as a fish seeks its food in the water. Their burrows are made, for the most part, by simply pushing the earth aside, and not by loosening the dirt and bringing it to the surface as is the habit with most burrowing animals. This necessitates enormous strength in the fore limbs and shoulders. Moreover there is need that these limbs be able to work in as small a space as possible. If we estimate the average diameter of a mole-run as two and a half inches, a simple computation will show that if the working distance of each fore limb were increased a quarter of an inch it would add at least 40 per cent. to the energy required for excavating every unit length of burrow. This ability to economize in working room is secured by the shortness of the fore limbs and still more by their position. Instead of being attached, as usual, on the side of the thorax, the whole pectoral girdle is brought forward around the neck. This is accomplished in the following manner: the sternum is produced forward in a separate keel-shaped bone, and the ventral attachment of the clavicle is to the front end of this.

Moles are found in all parts of the county excepting the flood-plains, but they are not in general very abundant on the bluffs or in cleared pastures excepting where these border on cultivated lands. They are fairly abundant in groves, but most so on the till plains and the moraines where the sod has been left unturned for a few years. They seem to prefer the neighborhood of cultivated lands, although they seldom venture far out into large fields under regular crop rotation.

The depth of their burrows below the surface of the ground varies considerably. In spring, autumn, and in damp seasons or in damp places in summer the burrows are at a depth of one to three inches. During summer and early autumn, when the ground is drier, they are at a depth of from four to eight inches. Others are still deeper—from eighteen inches to two feet—though these burrows are somewhat restricted in extent and are apparently found only in the vicinity of their nests.

The nests of moles are under logs or stumps or situated from six to eighteen inches—or perhaps deeper—below the surface. Those I have examined were made of nearly whole leaves and dried grass, and were all near a stump, tree, or fence. In all cases observed there were two or more exits, one of which led downwards to a deeper runway. In case a considerable area is occupied by moles, it will be found that runways of different moles are evidently connected, all burrows in the locality forming one extensive system, and it seems certain that many runs are used by several moles in common. However, in captivity moles are quarrelsome, and one can hardly imagine anything truly gregarious in their life. The persistence of the mole in keeping open a burrow once adopted as a main runway is remarkable. One often finds such runways crossing cow-paths or roadways, where they must be crushed in nearly every day, yet they are repaired, for months, as often as injured.

Apparently but few observations have been recorded on the breeding habits of moles. Our own observations indicate that there is but one litter a year, produced in April or May, and that from three to six constitute a litter.

The question as to how far moles may be beneficial or injurious to the farmer has been investigated by the State Laboratory of Natural History, and the results will be published in a later issue of this Bulletin. Only a short résumé of the results are called for here.

The annoyance and injury caused by the burrowing of moles in lawns, cemeteries, etc., is well known; but besides this mechanical and as it were accidental injury, gardeners and farmers have maintained that moles did other injury by eating newly planted seeds and the subterranean parts of garden vegetables. Extensive investigation in this state and elsewhere has shown conclusively that while by far the largest part of the food of the mole consists of worms, grubs, and insects, they do also eat a small amount of vegetable food. They burrow along the rows of newly planted corn and sometimes certainly eat it. They sometimes eat potatoes also, and possibly other root crops. On the other hand they undoubtedly do considerable good by destroying harmful insects in the larval or mature stage. Whether they do more harm than good depends on circumstances. There are occasions, however, when they become pests and should be destroyed.

They have few natural enemies. Birds of prey seldom take them, and the *Carnivora* that kill them are no longer common. They may be driven out of small areas by odors which are offensive to them. They are very sensitive to those of naphthalin, moth-balls, carbon bisulphid, formalin, and the like, or even kerosene. These substances put in and around their runs will drive them from the immediate locality. Our own attempts to poison them have been of uncertain success, as it has been difficult to determine, even approximately, the number killed. In captivity they eat bits of raw beef readily, and it seems probable that they might be poisoned by putting strychnine or arsenic on bits of meat and scattering them in the runs. Some claim to have had good success with poisoned sweet corn.

Trapping seems to be the most practical way of exterminating them. Of the various types of mole trap on the market, all have been found equally efficient, the only difference being a matter of price, convenience in manipulating, conspicuousness, and the like. It should be remembered that mole-runs are of two kinds: the temporary or exploring runways, which are driven in search of food, and which may never be entered again; and the main or permanent runways traversed every day. These latter are the ones on which the traps should be set. Whether a run is in use or not may be determined by crushing in the roof with the heel and watching for repairs. If in use it will be repaired, and usually within twenty-four hours.

## BATS.

### *CHIROPTERA*.

### SAY'S BAT.

*Myotis subulatus* (Say).

?*Vespertilio subulatus* Say, Long's Exped. Rocky Mts., II., 1823, p. 65.

This species has a general distribution throughout North America east of the Rocky Mountains.

Dental formula: *i*, $^2/_3$; *c*, $^1/_1$; *pm*, $^3/_3$; *m*, $^3/_3$.

The length of Say's bat is about like that of the little brown bat, 3.15–3.55 in. (80–90 mm.), but the fore arm is usually a trifle shorter—about 1.4 in. (34–37 mm.). The ears (Fig. 5) are long, reaching beyond the nose when laid forward. The tragus is very slender, and gave the bat its specific name, *subulatus* meaning awl-shaped.

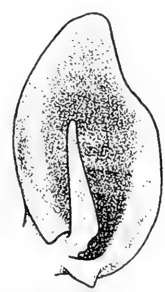


Fig. 5. Ear of Say's bat. (Miller.)

The color resembles that of the little brown bat, both species varying considerably in depth of color.

I have never taken this bat within the state, but in many localities it can not be uncommon. There is one specimen without data in our collections, and one from East Cairo, Ky. It is apparently very unevenly distributed. By some reliable observers it is reported as being uncommon, while others in similar environment report it as very abundant. It hibernates, and has been found in winter in hollow trees in immense numbers. The young are produced in June. Twenty pregnant females examined by Dr. Burt G. Wilder, each contained two young, as did also each of ten examined by Dr. A. K. Fisher*. More than this have been reported in a litter, but two is the usual number.

*Merriam's "Mammals of the Adirondack Region," p. 195.

## LITTLE BROWN BAT.

### *Myotis lucifugus* (Le Conte).

*Vespertilio lucifugus* Le Conte, McMurtrie's Ed. Cuvier's Animal Kingdom, I., App., 1831, p. 431.

The little brown bat is found throughout the whole of North America north of the southern boundary of the United States and between the Atlantic Ocean and the Rocky Mountains.

Dental formula: *i*, $^2/_3$; *c*, $^1/_1$; *pm*, $^3/_3$; *m*, $^3/_3$.

The length is 3.15–3.55 in. (80–90 mm.); fore arm, 1.50–1.54 in. (36–40 mm.). The wing-membranes are entirely naked except a narrow line close to the body. The ears are short for a bat, reaching barely to the tip of the nose when laid forward.

Fig. 6. Ear of little brown bat. (Miller.)

The hairs are everywhere blackish slate at base. The general color is dull brown, varying from wood-brown to sepia, with a distinct gloss in certain lights. The under parts are lighter.

The little brown bat and Say's bat closely resemble each other, but may be distinguished by the ears. The ears of the former (Fig. 6) when bent forward do not reach the tip of the nose, while those of Say's bat (Fig. 5) reach beyond the tip, and its tragus is more slender than that of the little brown bat, and is also different in shape.

Several bats of this species are preserved in a jar in the Laboratory collections, evidently having been found together somewhere in the state, but collection data are wanting. The species has been reported from Cook county and from Cairo, in Alexander county, and is undoubtedly not uncommon throughout the state.

## SILVER-HAIRED BAT.

### *Lasionycteris noctivagans* (Le Conte).

*Vespertilio noctivagans* Le Conte, McMurtrie's Ed. Cuvier's Animal Kingdom, I., 1831, p. 31.

This species ranges throughout the United States and north to the Peace River at least.

Dental formula: *i*, $^2/_3$; *c*, $^1/_1$; *pm*, $^2/_3$; *m*, $^3/_3$.

Ears (Fig. 7) short, nearly as broad as long, when laid forward reaching barely to nostril, basal lobe very large. Tragus short, straight, and bluntly rounded at tip, width much greater than length of anterior margin. The back of the interfemoral membrane is furred on the basal half.

The general color over all the body is a dark chocolate or seal-brown with white-tipped hairs. In general the individual hairs for the basal two-thirds are a dark seal-brown shading to a narrow band of richer color and abruptly tipped with white. The difference in general effect in the different parts of the body is due to the relative length of the white tips. On the head the white tips are short, while over the back they are long, giving a grizzled appearance to that part. The ears are dark clove-brown.

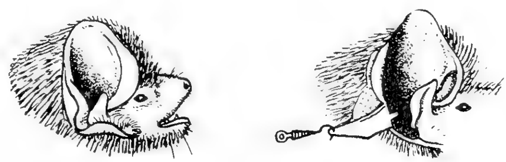


Fig. 7. Head and ear of silver-haired bat. (Miller.)

This species is one of the most common in this locality. It has often been taken on the campus and in the buildings of the University. It has been reported from various parts of the state, and is probably common throughout Illinois. Merriam says that the silver-haired bat in the Adirondacks hunts chiefly over the water-courses, but in this state it seems to be quite as common in towns and villages.

The young are produced in July. There are usually two in a litter.

In the northern part of its range it is said to migrate south in winter, but it is also found hibernating in hollow trees in New York State.

### GEORGIAN BAT.

*Pipistrellus subflavus* (F. Cuvier).

*Vespertilio subflavus* F. Cuvier, Nouv. Ann. Mus. d'Hist. Nat. Paris, 1832, p. 17.
*Vesperugo carolinensis* H. Allen, Monogr. Bats of N. A., 1893, p. 121. (Not *Vespertilio carolinensis* Geoff.)

The general range of this species is from the Atlantic coast west to Iowa, and south to eastern and southern Texas..

Dental formula: $i$, $^2/_3$; $c$, $^1/_1$; $pm$, $^2/_2$; $m$, $^3/_3$.

The length of the fore arm of this species is about 1.3 in. (34 mm.). The ear (Fig. 8) is rather long, extending just beyond the nostril when laid forward. The tragus is about half the length of the ear, with bluntly rounded tip.

The color is a light yellowish brown below. On the upper parts this color is clouded with a darker brown. The individual hairs on the back are plumbeous at base, yellowish brown to near the tip, which is dark brown. There are also longer hairs which are clear yellowish brown to the tip.

Fig. 8. Head and ear of Georgian bat. (Allen.)

The sixty-nine bats of this species in the Laboratory collections are undoubtedly Illinois specimens, but are without locality data. Kennicott found this bat at Cairo, in the extreme southern part of this state, and it was reported from Wisconsin by Strong, but not by later observers so far as I know. If it occurs in the northern part of Illinois it must usually be rare. Either the species is often overlooked or its distribution is very uneven over the most of its range. It is one of the species found in caves.

## BROWN BAT.

*Eptesicus melanops** Rafinesque.

(Annals of Nature, 1820, p. 2.)

*Vespertilio fuscus* Beauv., Cat. Peale's Mus. Phil., 1796, p. 14.
*Adelonycteris fuscus* H. Allen, Monogr. Bats of N. A., 1893, p. 112.

This species is generally distributed over the United States and the adjoining parts of the British provinces.

Dental formula: $i,\ ^2/_3;\ c,\ ^1/_1;\ pm,\ ^1/_2;\ m,\ ^3/_3$.

This is one of our larger bats, the total length being about 4.4 in. (110–112 mm.), and the length of the fore arm about 1.7 in. (43–46 mm.). The ears (Fig. 9) barely reach the nostril when laid forward. The basal third is furred on the outside, and there is a

* See Miller's (Gerrit S., Jr.) "The Families and Genera of Bats," Bull. 57, U. S. Nat. Mus., pp. 207–210.

sprinkling of hairs towards the front margin on the inside. The front margin is thickened.

The color varies from near cinnamon to clear bister or sepia, always being paler below. In our specimens it is bister above and hair-brown below. The base of the fur is dusky throughout.

This species has been reported from various parts of the state, and from the adjoining states. Two specimens have been taken at different times in the chemistry building of the University. H. Allen believes this species to be, on the whole, the most common bat in the United States. However that may be, the red bat has been taken far more often in this vicinity.

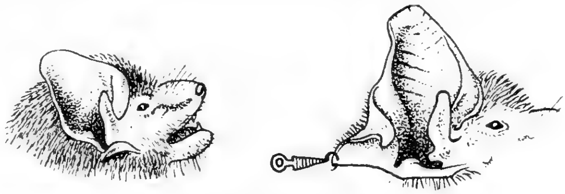


Fig. 9. Head and ear of brown bat. (Allen.)

It is not usually found hanging by its thumbs or feet, but rests with its folded wings flat upon some rough supporting surface, its head being down, In this latitude it is one of the species frequenting caverns and hibernating in them.

### RED BAT.

*Lasiurus borealis* (Müller).

*Vespertilio borealis* Müll., Natursyst., Suppl., 1776, p. 21.
*Atalapha noveboracensis* of Kennicott and various authors.

This species in its various forms is found throughout North America to the arctic regions. The typical form is found in eastern North America from Canada to Florida and Texas and west to Colorado. It is by far the most common bat in this vicinity, or at least the one most commonly taken.

The two species of *Lasiurus*, namely the red bat and the hoary bat, may be distinguished from all the other bats of the state by the fact that the portion of the flying membrane between the hind legs is entirely covered with thick fur on the outside. The red bat is the smaller of the two species. The fore arm is 1.35–1.6 in. (38–43 mm.) in length. The ears (Fig. 10) are very short and rounded for a bat, and the basal lobe has a notch in front which is lacking in the hoary bat. The border of the ear is light brown, and there is no clump of hair on the back of the fore arm.

On the back, neck, and head, the base of the hairs is reddish black abruptly changing to pinkish buff, and this in turn shading to bright chestnut. The tips of the longer hairs are white. The hairs on the posterior three-fourths of the interfemoral membrane lack the black at the base, otherwise they resemble those on the back. Toward the face the darker tips of the shorter hairs disappear, the general color being a light buff. There is a tuft of white hairs at the base of the thumb and along the base of the fourth finger. At the side of the neck the white tips of the hairs are so long that they form a white patch. The white tips are also rather more conspicuous over the throat than over the most of the body. The breast, the belly, and adjacent parts of the wing-membrane are a pale fawn-color.

Fig. 10. Head and ear of red bat. (Allen.)

According to Merriam* this species flies earlier in the evening than other bats do, and has even been seen flying in a cloudy afternoon. It is often taken here in the early evening within the city limits, especially in the early summer when encumbered with its young. It is frequently found attached to twigs of trees and shrubs, and in that position very closely resembles a dead leaf—an interesting example of protective mimicry.

The red bat and the hoary bat differ from all other bats in this vicinity in having four mammæ instead of two. The young are produced in May or June, and are two to four in number. They are nursed for some time, and are found clinging to the mother when they are at least half grown. I have never found more than two that were over one-fourth grown attached at the same time, however, though a female with a single half-grown one attached is very common. It is difficult to imagine how the mother could carry her whole family at once when they reach that size. The mothers show considerable attachment for their young, and if separated from them and frightened away are almost sure to return to look for them. I have kept the young of the red bat in captivity for some weeks

* "The Mammals of the Adirondack Region," p. 181.

feeding them on milk, which they learn to lap up. They become quite tame, and show as much intelligence and affection as most wild pets do.

### HOARY BAT.

*Lasiurus cinereus* (Beauvois).

*Vespertilio linereus* Beauv., Cat. Peale's Mus. Phil , 1796, p. 15. (Obvious misprint for *cinereus*.)
*Atalapha cinerea* of Kennicott and various authors.

This species, though apparently seldom abundant in the United States, ranges throughout North America from the Atlantic to the Pacific, north to Athabasca at least, and south through Mexico and Central and South America to Chili. It breeds in Canada and the northern United States, but migrates south in winter.

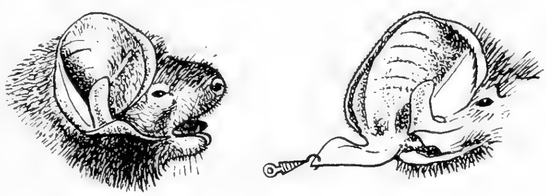


Fig. 11. Head and ear of hoary bat. (Allen.)

The general shape of this bat is like that of the red bat, but it may be distinguished from that species by characters already designated; namely, by its larger size (fore arm over 2 in., or 50 mm., in adults), by the blackish borders of the ears (Fig. 11) and the absence of a notch in their lower lobes, and by the distinct patch of fur near the base of the fore arm.

The color varies considerably, but the following description applies to the few Illinois specimens that I have seen: The general color is a mixture of light yellowish brown, deep umber-brown, and white, the yellowish brown being clear and unmixed on throat, head, and under side of membranes, the umber-brown predominating on the back and on the dorsal surface of the interfemoral membrane, where, however, the hairs are mostly tipped with silvery white, sometimes to so great an extent as nearly to conceal the dark tints beneath. The lips, chin, and cheeks are sprinkled with short blackish hairs. On the ventral surface white predominates on the belly, between which and the yellow of the throat is a band in which the umber-brown is more conspicuous than elsewhere on the under parts. There are tufts of light yellowish brown fur at the bases of the thumb, fifth finger, and fore arm, like the fur on the under side of the wing-membranes. On the middle of the back the individual hairs are colored as follows: deep plumbeous at base, light yellowish brown (shading to umber towards apex) through middle half, umber-brown near apex, silvery white at tip.

But little has been recorded of the habits of this bat. It is a strikingly large and handsome species, but seems to be nowhere abundant. There are probably two to four young, for females with all four mammæ used have been taken. In the northern part of its range it migrates south in winter.

### RAFINESQUE'S BAT.

*Nycticeius humeralis* (Rafinesque).

*Vespertilio humeralis* Raf., American Monthly Magazine, III., 1818, p. 445.

This bat is found from eastern United States west to Arkansas and western Texas.

Dental formula: *i*, $^1/_3$; *c*, $^1/_1$; *pm*, $^1/_2$; *m*, $^3/_3$.

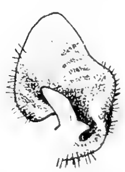


Fig. 12. Ear of Rafinesque's bat. (Miller.)

The length of the fore arm is 1.3–1.65 in. (34–38 mm.). The ears (Fig. 12) are thick and leathery. The tragus is short, blunt, and broad, and is bent slightly forward.

The fur is everywhere plumbeous at extreme base. The remainder of the hair varies from burnt umber to mummy-brown over the back, and from raw umber to hair-brown below. There are occasionally other variations in color.

This species is not rare in this county. It seems to be somewhat less likely to be found around towns than some other species of bats.

# THE ECOLOGICAL SUCCESSION OF MAMMALS IN CHAMPAIGN COUNTY.

In the two accompanying charts (Pl. XXVII. and XXVIII.) an attempt has been made to represent graphically the variation in the abundance of the principal species of mammals in this region since the advent of white men. The second one is purely chronological, and applies only to Champaign county. The first one, however, represents the variations in the abundance of our mammals as related to the degree in which advancing civilization has modified primitive conditions, and is therefore more general in character, and should in a good degree be true for other sections in the prairie region of the Mississippi Valley.

A brief explanation of the nomenclature used in this chart to designate the progressive stages of civilization follows, the order observed corresponding to their consecutive occurrence.

(1) *The period of the explorer and hunter.* During this period the physiographic condition of the country remained unchanged, but the numbers of certain large animals were greatly diminished.

(2) *The period of the squatter and the range.* In this period settlements were begun, usually in timber near streams. Only a very small portion of the country was enclosed by fences or under cultivation, the settlers feeding their horses, cattle, and hogs largely on the natural products of the prairie and the forest. They were obliged to wage war on the larger carnivores in self-defense, and they hunted the most valuable fur-bearing animals for gain.

(3) *The period of settlement.* This is the time during which the land was practically all taken up by settlers or land speculators. Pasturage on public domain ceased, and considerable portions of the land were enclosed. Timber for the construction of buildings and fences was entirely from the local supply, and considerable areas of woodland were cleared for cultivation. In consequence of these inroads into the forests and the settling of the prairie the larger animals still remaining, such as deer, wolves, and wildcats, were greatly thinned out, but the extensive wooded-belts along the rivers still sheltered a few of them.

(4) *The improvement period.* This term serves to indicate the stage in which original prairie was drained and plowed, and woodland cleared and plowed—or at least so thinned out and pastured as to be profoundly modified in character. The cultivated ground is supposed to be either pasturage or land under rotation of crops. This is the present stage of by far the greatest part of the county.

(5) *The market-garden stage.* This term represents continuous and intense cultivation of limited areas of the land.

(6) *The village stage.* This expression has reference to the stage of advancement in which houses are built separate from each other and considerable areas devoted to yards and gardens.

(7) *The city stage.* This period is reached when the buildings touch each other, and there is practically no open ground for mammalian life.

Of course these various stages grade into each other, and in only a limited portion of the county here and there would there be simultaneous attainment to any of the later stages. Moreover, it is evident that the early stages must hold over an area considerably larger than a single county in order to be characterized by distinctive mammalian life, while the later stages may prevail over progressively smaller and smaller areas and still be so characterized.

In the charts the lines represent the presence of the different animals, the varying size of each line indicating the relative abundance of that single species at different times, or during different stages of civilization. There is in the charts no comparison of one animal with another. A species is regarded as present so long as it seems certain that it bred within the county. Stragglers of deer and other large animals were seen much later than is indicated.

The data used in making the charts were gotten in various ways. The reminiscences of early settlers as to variation in the abundance of the larger animals have been utilized, and though differing in detail they agree very well, on the whole, in regard to the most important general facts. The early records of travel through the state also furnished some data; and, lastly, the study of present distribution has thrown much light on the conditions favorable to each particular species. While the charts are not to be taken as exact mathematical representations of the variation in abundance of our mammals, either chronologically or with reference to the stages of civilization, it is believed that they may give a tolerably accurate idea of the change that has taken place in the mammalian population since the coming of the white man.

I can find no definite record of buffalo within the county. The early settlers often found buffalo skulls and buffalo-wallows, and buffalo-trails were common,—all showing the earlier abundance of the animals. Hornaday estimates that they left this part of Illinois about 1810.* A number of the very earliest settlers think that buffalo were seen here considerably later than that, but are unable to give positive facts. At any rate the main herd left about 1810. The elk also must have left about the same time. It should be remembered that this part of the state was surrounded by settlements on all sides before it was itself settled, and so the larger game was frightened off earlier than usual in the development of the country.

Beaver were seen, according to Mr. Parsons, of Homer, so late as 1860 in the vicinity of Broadlands. There were but few left, however, in 1835. The bear and the panther must certainly both have been occasional visitants, but I am unable to fix the date of their last appearance. They had disappeared by 1840, and the other large *Carnivora* had been thinned out. In consequence the deer were beginning to increase, and all accounts agree that there was a period of greatest abundance of deer about 1850. In a similar manner the destruction of the wolves and wildcats was followed by an increase in the abundance of foxes, raccoons, opossums, and skunks, till these, in turn, were killed off by man.

Following the diminution of the wolves and foxes there is also a period of greatest abundance of rabbits, and I believe that at present, each fall before the shooting season opens these animals are as abundant as they were under the conditions prevailing before the settlers came. The period of great abundance of squirrels, as indicated on the chart, was determined by various records. How far this abundance may have been due to the destruction of the large carnivores, and how far due to other agencies, I am unable to tell. All the rodents are subject to periodical fluctuations in abundance due to a combination of circumstances not fully understood.

In the case of weasels and shrews no variation in abundance is indicated in the chronological table. While there can be no doubt

* Rep. U. S. Nat. Mus. for year ending June 30, 1887, Map (following p. 548).

that certain stages of improvement are especially favorable for these species, these conditions exist in only a part of the county at a time, and are balanced by unfavorable ones elsewhere.

In general there has been a uniform diminution of fur-bearing animals from the first. The exception we note, is that of the musk-rat. Of late years, owing to the low value of their skins and to the general prosperity and consequent increased means of earning money, the muskrats have not been so extensively trapped as formerly, and I believe that they are at least holding their own in the county. At present the improved drainage and increased use of underground drains are the most unfavorable conditions for the species.

In the case of bats, so far as available data go, the favorable and unfavorable changes—for example, destruction of birds of prey, on the one hand, and removal of forests, on the other—about balance; and while there must have been some fluctuations in the number of the bats in the county from year to year, and probably permanent variations in the relative abundance of the species, on the whole the number present now does not differ greatly from what it was a century ago, nor do we know of any great waves of increase or decrease since the first settlement of the country.

In the case of the smaller rodents—gophers, rats, and mice—there has probably been a continued increase from the first permanent coming of white men. The reason is evident. Man has furnished abundant food for these animals and has destroyed their worst enemies.

Buffalo and elk were wholly exterminated by hunters, and the beaver nearly so, before the first settlement in the county. The squatters and early settlers destroyed the larger *Carnivora* in self-defense, and this was followed during the early settlement and improvement stages by an increase of deer, opossum, and such smaller carnivores as raccoons, foxes, skunks, and weasels. As these smaller *Carnivora* are themselves diminished by man's persecution, the rabbits and smaller rodents increase, and this increase continues tll a high degree of cultivation is attained. In the final stages of village and city all the *Mammalia* disappear except the bats—which remain in little-changed numbers—and the rats and mice, which are continually increasing.

# NOTE.

## Preparation of Poisoned Bait for Small Mammals.

The following method of preparing a poisoned bait for prairie-dogs, gophers, rats, and mice is recommended by the U. S. Department of Agriculture:

Dissolve one ounce of strychnia sulphate in a pint of boiling water, add a pint of thick sugar-sirup and stir thoroughly. The above quantity is enough to poison half a bushel of grain or corn, but smaller proportional quantities of grain and sirup may be mixed as desired. Wheat, corn, oatmeal, or corn-meal may be used. If, after thorough mixing, the solution is not sufficient to wet all the grain used, add a little water. Let the poisoned grain stand over night. If the grain is too wet, add a little corn-meal to take up the moisture. The oatmeal bait may be used immediately after mixing.

It should never be forgotten that whatever will poison vermin will poison other animals also, and too great care can not be used in handling any poisoned bait. The following poison is less dangerous to larger animals than the above, and is especially recommended for rats and mice.

Take one part of barium carbonate and four parts of flour or meal, add a little sweetening, and mix into a dough. Cut into pieces the size of a pea for mice, and about four times that size for rats.

For destroying carnivorous animals, meat poisoned with arsenic is the usual bait. We believe, however, that there is very little necessity for the use of such means of destruction in this state. Hunting or trapping will be quite as effective, and we believe quite as cheap in the end.

# BIBLIOGRAPHY.


Adams, Chas. C.

'06. Notes on the Mammals of the Porcupine Mountains and Isle Royale, Michigan. Rep. State Board Geol. Surv. Mich., 1905, pp. 128–133.

'09. Notes on Isle Royale Mammals and their Ecological Relations. Rep. State Board Geol. Surv. Mich., 1908, pp. 389–422.

Adams, Sherman W.

'96. The Native and Wild Mammals of Connecticut. Read before Conn. Hist. Soc. Feb. 4, 1896. Hartford, Ct.

Allen, Glover M.

'04. Fauna of New England. 3. List of Mammalia. Occasional Papers Boston Soc. Nat. Hist., VII.

Allen, J. A.

'71. Mammals and Winter Birds of Eastern Florida. Bull. Mus. Comp. Zool. Harvard Coll., Vol. II., No. 3.

'76. Geographical Variation among North American Mammals. Bull. U. S. Geol. and Geogr. Surv. Terr., Vol. II., pp. 309–350.

'94. Notes on Mammals from New Brunswick, with Description of a New Species of Evotomys. Bull. Am. Mus. Nat. Hist., Vol. VI., pp. 99–106.

'94a. On the Mammals of Aransas County, Texas, with Descriptions of New Forms of Lepus and Oryzomys. Bull. Am. Mus. Nat. Hist., Vol. VI., pp. 165–198.

'94b. Remarks on a Second Collection of Mammals from New Brunswick, and on the Rediscovery of the Genus Neotoma in New York State. Bull. Am. Mus. Nat. Hist., Vol. VI., pp. 359–364.

'98. Revision of the Chickarees, or North American Red Squirrels (Subgenus Tamiasciurus). Bull. Am. Mus. Nat. Hist., Vol. X., pp. 249–298.

'01. A Preliminary Study of the North American Opossums of the Genus Didelphis. Bull. Am. Mus. Nat. Hist.. Vol. XIV., pp. 149–188, Pl. XXII–XXV.

Bailey, Vernon.

'95. The Pocket Gophers of the United States. Bull. No. 5, Div. Ornith. and Mamm., U. S. Dept. Agr. 46 pp., 6 fig., 1 map.

'05. Biological Survey of Texas. N. Am. Fauna, No. 25. 222 pp., 23 fig.

Baird, Spencer F.

'57. Mammals of North America. Reports of Explorations and Surveys to ascertain the most Practicable and Economical Route for a Railroad from the Mississippi River to the Pacific Ocean, Vol. VIII., Pt. I. 757 pp., 60 pl., 35 text fig.

Bangs, Outram.

'98. The Land Mammals of Peninsular Florida and the Coast Region of Georgia. Proc. Boston Soc. Nat. Hist., Vol. XXVIII., pp. 157–235. 1 map, 8 text fig.

Banta, Arthur M.

'07. The Fauna of Mayfield's Cave. Pub. 67 Carnegie Institution of Washington. 114 pp., 2 pl., 13 text fig.

Brayton, A. M.

'82. Report on the Mammalia of Ohio. Rep. Geol. Surv. Ohio, Vol. IV., Pt. I., pp. 1–185.

Brimley, C. S.

'05. A Descriptive Catalogue of the Mammalia of North Carolina exclusive of the Cetacea. Journ. Elisha Mitchell Sci. Soc., Vol. XXI., pp. 1–32.

Bryant, W. E.

'91. A Provisional List of the Land Mammals of California. Zoe, Vol. I., pp. 353–360.

Butler, Amos. W.

'91. Our Smaller Mammals and their Relation to Horticulture. Trans. Ind. Hort. Soc., Vol. XXXI. 7 pp.

'91a. On Indiana Shrews. Proc. Ind. Acad. Sci., 1891, pp. 161–163.

Carey, Merritt.

'07. Some Unrecognized Colorado Mammals. Proc. Biol. Soc. Washington, Vol. XX., pp. 23–28.

Chapman, Frank M.

'94. Remarks on Certain Land Mammals from Florida, with a List of the Species known to occur in the State. Bull. Am. Mus. Nat. Hist., Vol. VI., pp. 333–346.

Coues, Elliott.

'71. Notes on the Natural History of Fort Macon, N. C., and Vicinity. (No. 1.) Proc. Acad. Nat. Sci. Phila., 1871—Mammals, pp. 12–18.

'77. The Fur-bearing Animals. A Monograph of North American Mustelidæ. U. S. Geol. Surv. Terr., Misc. Pub. No. 8. 348 pp., 20 pl.

De Kay, James E.

'42. Zoology of New York or the New York Fauna. Part I. 146 pp., 33 pl.

Elliot, D. G.

'96. On sundry Collections of Mammals received by the Field Columbian Museum. Pub. 11 Field Mus. Nat. Hist., Zool. Ser. Vol. I., No. 3. 17 pp., 10 illustr.

'98. Lists of Species of Mammals, principally Rodents, obtained by W. W. Price, S. E. Meek, G. K. Cherrie and E. S. Thompson, in the States of Iowa, Wyoming, Montana, Idaho, Nevada and California, with Descriptions of New Species. Pub. 27 Field Mus. Nat. Hist., Zool. Ser. Vol. I., No. 10. 32 pp.

'01. Synopsis of the Mammals of North America and the Adjacent Seas. Pub. 45 Field Mus. Nat. Hist., Zool. Ser. Vol. II. 471 pp., 143 illustr.

'04. The Land and Sea Mammals of Middle America and the West Indies. Pub. 95 Field Mus. Nat. Hist., Zool. Ser. Vol. IV., Pt. 2. 424 pp., 196 illustr.

'07. A Catalogue of the Collection of Mammals in the Field Columbian Museum. Pub. 115 Field Mus. Nat. Hist., Zool. Ser. Vol. VIII. 694 pp., 92 illustr.

Emmons, Ebenezer.
'40. A Report on the Quadrupeds of Massachusetts. Reports on Herbaceous Plants and Quadrupeds of Mass. 83 pp.

Garman. H.
'94. A Preliminary List of the Vertebrate Animals of Kentucky. Bull. Essex Inst., Vol. XXVI., Nos. 1, 2, 3. 63 pp.

Grinnell, Joseph.
'08. The Biota of San Bernardino Mountains. Univ. Calif. Pub. in Zool., Vol. V., No. 1—Mammals, pp. 134–160. 170 pp., 24 pl.

Hahn, Walter L.
'06. Notes on Mammals of the Kankakee Valley. Proc. U. S. Nat. Mus., Vol. XXXII., pp. 455–464.

Herrick, C. L.
'92. The Mammals of Minnesota. A Scientific and Popular Account of their Features and Habits. Bull. No. 7, Geol. and Nat. Hist. Surv. Minn. 299 pp., 8 pl., 23 text fig.

Holder, Chas. F.
'07. Half Hours with Mammals. 253 pp. New York.

Hollister, N.
'09. Notes on Wisconsin Mammals. Bull. Wis. Nat. Hist. Soc., Vol. VI., pp. 137–142.

Howell, Arthur H.
'09. Notes on the Distribution of certain Mammals in the Southeastern United States. Proc. Biol. Soc. Washington, Vol. XXII., pp. 55–68.

Jackson, Hartley H. T.
'07. Notes on the Mammals of Southwestern Missouri. Proc. Biol. Soc. Washington, Vol. XX., pp. 71–74.

'08. Preliminary List of Wisconsin Mammals. Bull. Wis. Nat. Hist. Soc., Vol. VI., pp. 13–34. 1 pl.

Kennicott, Robert.
'55. Catalogue of Animals observed in Cook county, Illinois. Trans. Ill. State Agr. Soc., Vol. I., 1853–54, pp. 577–595.

'57, '58. The Quadrupeds of Illinois Injurious and Beneficial to the Farmer. Rep. Comm. Patents, 1856, pp 52–160, Pl. I—XLVI. (Reprint in Trans. Ill. State Agr. Soc., Vol. II., 1856–57, pp. 615–684, Pl. V.–XIV.); Idem, 1857, pp. 72–107; 1858, pp. 241–256.

Knox, M. V. B.

'75, '76. Kansas Mammalia. Trans. Kan. Acad. Sci., Vol. IV., pp. 18–22; Vol. V., p. 64.

Lantz, D. E.

'05. Kansas Mammals in their Relation to Agriculture. Bull. No. 129, Exper. Station Kan. State Agr. Coll. 74 pp., 1 illustr.

Lyon, Marcus Ward.

'04. Classification of the Hares and their Allies. Smithsonian Misc. Collections, Vol. XLV. (Quart. Issue, Vol. I.), No. 1456, pp. 321–447. Pl. LXXIV—C, Fig. 44, 45.

MacFarlane, R.

'05. Notes on Mammals collected and observed in Northern Mackenzie River District, Northwest Territories of Canada, with Remarks on Explorers and Explorations of the Far North. Proc. U. S. Nat. Mus., Vol. XXVIII., pp. 673–764. 5 pl.

McAtee, W. L.

'07. List of the Mammals, Reptiles and Batrachians of Monroe County, Indiana. Proc. Biol. Soc. Washington, Vol. XX., pp. 1–16.

Mearns, Edgar A.

'98. Study of Vertebrate Fauna of Hudson Highlands, with Observations on the Mollusca, Crustacea, Lepidoptera, and the Flora of the Region. Bull. Am. Mus. Nat. Hist., Vol. X., pp. 303–352.

'98a. Notes on the Mammals of the Catskill Mountains, New York, with General Remarks on the Fauna and Flora of the Region. Proc. U. S. Nat. Mus., Vol. XXI., pp. 341–360.

Merriam, C. Hart.

'73. Report on the Mammals and Birds of the Expedition. Sixth Ann. Rep. U. S. Geol. Surv. Terr., 1872—Mammals, pp. 661–669.

'82, '84. The Mammals of the Adirondack Region. Trans. Linn. Soc. N. Y., Vol. I, pp. 9–107; Vol. II., pp. 108–312. Also author's reprint. L. S. Foster, N. Y.

'91. Results of a Biological Reconnoissance of South-central Idaho· N. Am. Fauna, No. 5—Mammals, pp. 31–87. 4 text fig.

Miller, Gerrit S., Jr.

'94. A Collection of Small Mammals from the New Hampshire Mountains. Proc. Bost. Soc. Nat. Hist., Vol. XXVI., pp. 177–197, Pl. III., IV.

'97. Notes on the Mammals of Ontario. Proc. Bost. Soc. Nat. Hist., Vol. XXVIII., pp. 1–44.

'99. Preliminary List of the Mammals of New York. Bull. N. Y. State Mus., Vol. VI., No. 29. 116 pp.

Miller, Gerrit S., Jr., and Rehn, James A. G.

'01, '04. Systematic Results of the Study of North American Land Mammals to the close of the year 1900. Proc. Bost. Soc. Nat. Hist., Vol. XXX., pp. 1–352. [Continuation of same] during the years 1901 and 1902. Ibid., Vol. XXXI., pp. 61–145.

Mitchell, P. Chalmers.

'05. On the Intestinal Tract of Mammals. Trans. Zool. Soc. London, Vol. XVII., pp. 437–536. 50 text fig.

Nash, C. W.

'05. Check List of the Vertebrates of Ontario and Catalogue of Specimens in the Biological Section of the Provincial Museum—Mammals, pp. 19–32. Dept. of Education, Toronto. Printed by order of Legislative Assembly of Ontario.

Nelson, E. W.

'09. The Rabbits of North America. N. Am. Fauna, No. 29. 314 pp., 13 pl.

Nelson, Julius.

'90. Descriptive Catalogue of the Vertebrates of New Jersey. Geol. Surv. N. J., Final Rep. of State Geologist, Vol. II., Pt. II., pp. 489–776.

Osborn, Herbert.

'92. A Partial Catalogue of the Animals of Iowa represented in the Collection of the Department of Zoology and Entomology of the Iowa Agricultural College. Published by authority of Trustees. Ames, Iowa. 39 pp.

Osgood, Wilfred H.

'09. Revision of the Mice of the American Genus Peromyscus. N. Am. Fauna, No. 28. 285 pp., 8 pl., 12 text fig.

Plummer, J. T.

'44. Quadrupeds about Richmond, Wayne County, Indiana. Pp. 244–249 in Scraps in Natural History (Quadrupeds), in Amer. Journ. Sci. and Arts, Vol. XLVI.

Preble, Edward.

'02. A Biological Investigation of the Hudson Bay Region. N. Am. Fauna, No. 22. 140 pp., 14 pl.

'08. A Biological Investigation of the Athabaska-Mackenzie Region. N. Am. Fauna, No. 27. 574 pp., 25 pl.

Rhoads, Samuel N.

'96. Contributions to the Zoology of Tennessee. No. 3, Mammals. Proc. Acad. Nat. Sci. Phila., 1896, pp. 175–205.

'03. The Mammals of Pennsylvania and New Jersey. A Biographic, Historic, and Descriptive Account of the Furred Animals of Land and Sea, both Living and Extinct, known to have existed in these States. Privately published. Philadelphia. 266 pp., 9 pl.

Roosevelt, Theodore, Van Dyke, T. S., Elliott, D. C., and Stone, A. J.

'02. The Deer Family. The Macmillan Co., New York. 334 pp., 25 illustr., 7 maps.

Shufeldt, R. W.

'97. Chapters on the Natural History of the United States. Studer Bros., New York. 472 pp., 128 text fig.

Snyder, W. E.

'02. A List, with brief notes, of the Mammals of Dodge Co., Wis. Bull. Wis. Nat. Hist. Soc., Vol. II., n. s., pp. 113–126.

Stone, Witmer.

'08. The Mammals of New Jersey. Ann. Rep. N. J. State Mus., 1907, Pt. II., pp. 33–110. 58 pl.

Strong, Moses.

'79. List of Mammals of Wisconsin. Geol. of Wis., Vol. I.(1873–1879). 440 pp.

Swenk, Myron H.

'09. A Preliminary Review of the Mammals of Nebraska, with Synopses. Pub. Neb. Acad. Sci., Vol. VIII., No. 3, pp .61–96 +. (In course of publication.)

Thomas, Cyrus.

'61. Mammals of Illinois. Catalogue. Trans. Ill. State Agr. Soc., Vol. IV., 1859–60, pp. 651–661.

Tyrrell, J. B.

'88. Catalogue of the Mammalia of Canada Exclusive of the Cetacea. Proc. Canadian Inst., 3d Ser., Vol. VI., Fasc. No. 1, pp. 66–91.

Warren, Edward R.

'06. The Mammals of Colorado. Colorado Coll. Pub., Gen. Ser. No. 19, Sci. Ser. No. 46, pp. 225–274.

'08. Further Notes on the Mammals of Colorado. Colorado Coll. Pub., Gen. Ser. No. 33, Engineering Ser. Vol. I., No. 4, pp. 64–89.

Warren, G. K.

'75. Preliminary Report of Explorations in Nebraska and Dakota in the Years 1855–56–57. 125 pp., 1 map. Reprint from Appendixes to Rep. Sec. War, Dec., 1858.

## Plate XXVI.

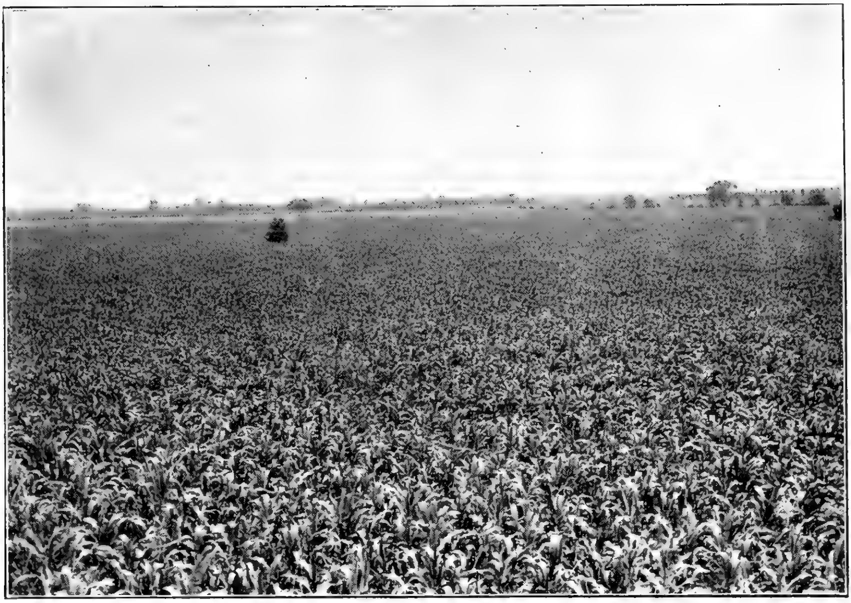


Fig. 1. View in the till plain. Moraine ridge in background. Habitat of white-footed prairie-mouse.

Fig. 2. A permanent pasture. Habitat of white-footed wood-mouse. Striped gophers and moles are common.

Plate XXVII.

Cultural Chart of Variations in Abundance of Mammals of Champaign Co., Ill.

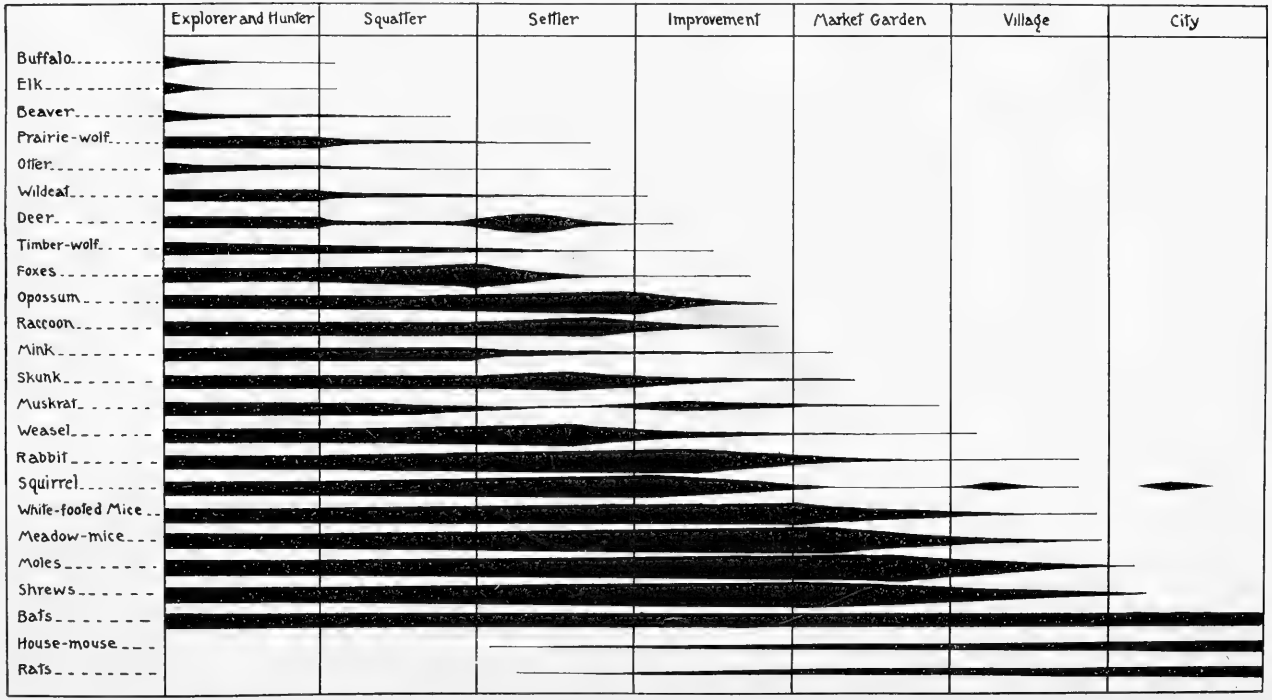
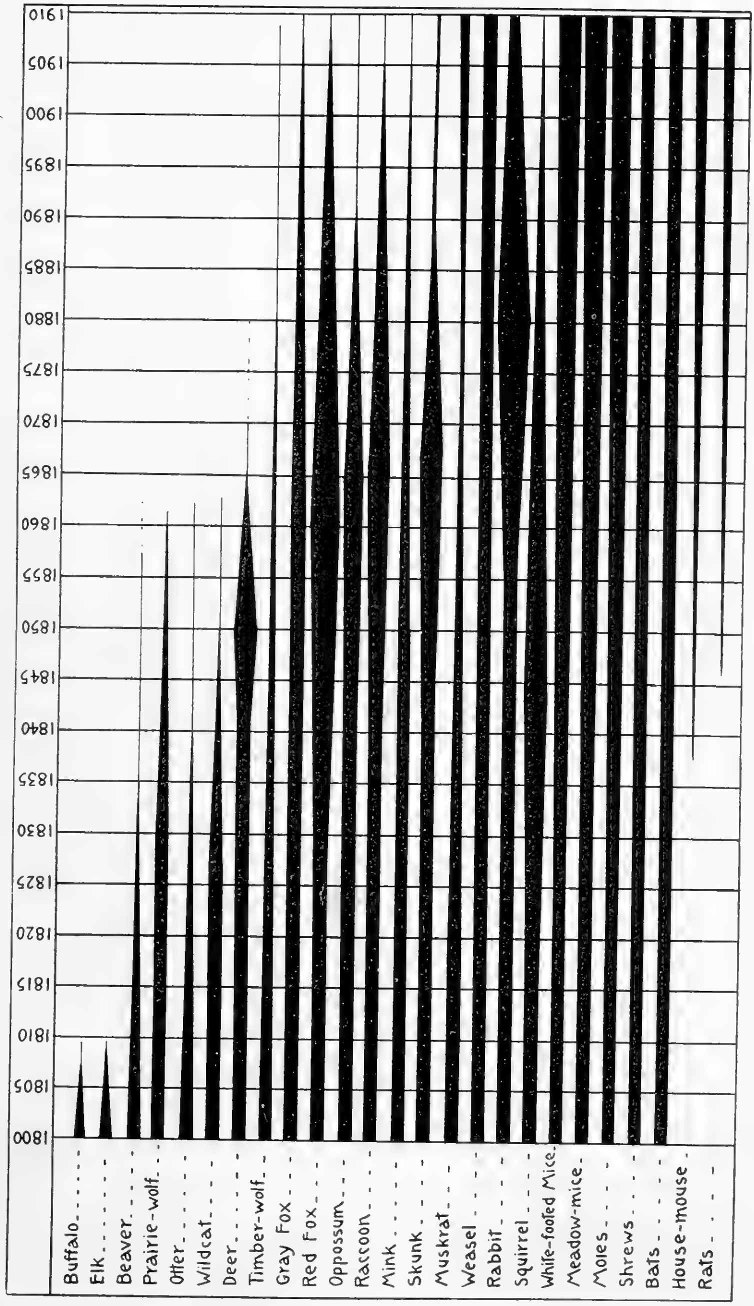


PLATE XXVIII.




HISTORICAL CHART OF VARIATIONS IN ABUNDANCE OF MAMMALS OF CHAMPAIGN CO., ILL.

# BULLETIN

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